ELECTRIC LIGHTING.

A PRACTICAL TREATISE

BY

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Translated from the French

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WITH FORTY-EIGHT ENGRAVINGS IN THE TEXT.

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PREFACE.

OUR purpose in publishing this work is to show what are, in the present state of science, the judicious applications of electric lighting; as much to record the services that this new light is capable of rendering to a multitude of industries, as to combat false ideas founded on the possibility of its universal use.

Few questions have at the present time the advantage of exciting public attention to the extent of this one; trials have been made in France, England, Germany, Russia, Belgium, Sweden, Austria, Spain, America; on vessels, quays, and dock-yards; in workshops, harbours, fortifications, railway stations, &c., &c. It is of general interest.

In this century, when progress is so rapid, many persons do not await the sanction of experience before exalting a new invention to the detriment of all others; these persons have scarcely had time to admire the marvellous effects of gas-lighting than they salute the dawn of electric lighting by proclaiming that it is a hundred times more economical than the former, that we can employ it everywhere, distribute it indefinitely, and that its light is as beautiful and intense as that of the sun itself.

Other persons, unfortunately more numerous than the former, wish no departure from routine, and hinder by their inertia the march of all progress. For them, the electric light has no industrial existence; it is a will-o'-the-wisp, dazzling those who regard it, and so fatiguing the eye that its use is materially impossible.

We ignore surprises that the future may reserve for us; but our knowledge of the subject leads us to affirm that the *rôle* of electricity is far from its full development, especially from the point of view of the transformation of motion into light. It is

not of so much importance to know what will be, as to know what is. And it is to this end that we present a study of the elements of electric lighting that have definitely entered the domain of practice, and of the best conditions for its use. Later, as perfections are more nearly attained, we shall put them so much better to profit, that we can better appreciate the advantages; it appears to us irrational to neglect the use of what is already good, under the pretext that we shall one day arrive at something more nearly perfect.

The electric light may be utilised in two ways, either by powerful foci illuminating or visible at great distances, or by less intense foci giving a light suitable to all kinds of night work. In the first case, nothing can equal the services rendered by electricity; in the second case, there is no longer comparison, the advantage being sometimes in favour of gas, oil, petroleum, &c., sometimes in favour of electricity.

Thus for lighthouse service, fortifications, maritime service, shores, armies in campaign, the electric light is superior to all others; for show-rooms and manufactories, for open-air yards and large workshops, it is equally suitable; for domestic household illumination, and for certain trades carried on under low roofs, where there are numerous local subdivisions, gas, oil, or petroleum is preferable. In many establishments lighted by gas it has been advantageous to substitute electricity.

In any case the number of applications would be very limited if we should continue to deprive ourselves of light, as it is the custom to do in the majority of manufactures, where during the night superintendence is impossible, where the work produced during the night is much less than in the day. But, we hasten to add, this *statu quo* is not to be feared; some intelligent manufacturers—and their number is great—will replace their present system of lighting by a system of lighting four or five times more intense, and they will not hesitate to admit that their products are better, in larger quantities, and consequently more economical; this example will not be lost, and to sustain competition their fellow-manufacturers will imitate them.

In support of this opinion it is sufficient to recollect that the Gramme machine, with which the electric light is practically

obtained, had not last year * more than a dozen applications, whereas to-day it numbers more than two hundred. However, this new machine has not failed to receive criticism. It has been said to become heated, difficult to work, clumsy, capricious, that it could not be worked ten hours without repairs. The truth is, it works perfectly, and, instead of deteriorating, improves by use.

Our work is divided into twelve chapters. The first six are devoted to the study of the voltaic arc, the carbons, the lamps or regulators, and some magneto-electric machines; the last six treat of realised applications, the comparative costs of several sources of illumination, of lighting by incandescence, and of the division of the electric light.

Those persons simply seeking for information as to the possibility of utilising the electric light for themselves, should read Chapters VII., VIII., and IX., which contain all the necessary information for planning and appreciating the advantages to be gained by this system of illumination.

We have dwelt somewhat on experiments made by scientific men to determine the nature and properties of the voltaic arc; this was the origin of the new method, and it is important to explain thoroughly the phenomena which have given birth to the remarkable applications that we subsequently cite, in order to admit of the better exercise of judgment.

The study of regulators or lamps could have been made the subject of a special work as regards the proposed and attempted types; but most of these apparatus have numerous drawbacks, and we have preferred to mention only those presenting originality, such as might serve as basis for a new invention, or warn seekers against combinations judged impracticable. M. Serrin's apparatus should have, and in effect has, the honours of our record, as being to the present time the only one susceptible of advantageous use in industry.

The manufacture of carbon rods, intended to supply the regulators and to become heated under the influence of the electric fluid, has an exceptional importance; upon this, perhaps, depends the success of electric lighting. To this we have

* M. Fontaine writes in 1877.—TRANS.

devoted a long chapter, and have minutely detailed the processes of Messrs. Carré and Gaudoin, which are the most perfect. Some exact experiments on the quantity of light produced by several carbons complete these descriptions.

Before attempting the study of the Gramme machine, we have passed in review the principal magneto-electric machines that have preceded it, and, with the aid of numerous engravings, we hope to have made clear, even to those little initiated in modern physics, the principle of these marvellous machines that create such torrents of electricity without acid or consumption of metal—with nothing more than the influence of magnets and coils of copper in relative motion.

The Gramme machine being applied only in constructive workshops, it is useful to speak of it at length; to well distinguish its principle, its mode of construction, and its multiple effects. Here again it has been necessary to make use of drawings in order to explain the apparatus and show the several forms it has assumed.

But it is especially in the part devoted to the applications that we have entered into precise detail, by insisting particularly on the motive force expended, and on the true cost price of the electric light. To evaluate the motive force, we have at our disposal the reports of Messrs. Tresca, Member of the Institute (of France); Hagenbach, Professor at the University of Bâle; and Schneider, Professor of Physics at Mulhouse. For the comparison of the cost prices of several lights, we have drawn upon some sources of authority, chiefly from persons who have for several years employed this new system of lighting. The applications to marine, artillery, or civil purposes have not been signalised by great development; for the several Governments who have experimented with the Gramme machine have kept secret all the results observed. Nevertheless, numerous and important orders, obtained after prolonged trials, authorise us in saying that success has been complete.

Mechanical workshops have been the first to make use of the electric light; also dyers, who need a very white light; and sugar refineries, where steam is produced very economically. Railway companies have adopted it for the illumination of their

goods depôts; contractors for public works, for the execution during the night of earthworks or mason-work; finally, it has been introduced with success into spinning mills, smithies, foundries, &c.

Three years ago much was said about a new system of electric lighting, the invention of a Russian professor, which consisted in causing the incandescence of a small rod of carbon. It was for some time believed that by the aid of this invention the light could be in some way indefinitely divided, and introduced everywhere for nearly nothing. Deeper study of this subject, and numerous direct experiments, have enabled us to reduce this system to its real value, which, if it be defective when we consider it as capable of causing a revolution in present lighting, is very remarkable, on the other hand, when we have in view only a small number of special applications.

The Jablochkoff candles, about which also much was said, appear to us to merit the same appreciation. If they result in anything practical, which is very possible, they will be useful in certain cases, but will be substitute for nothing absolutely. In spite of our sympathy for the inventor, we have to guard the reader against the exaggerations founded on some experiments made in a Paris warehouse, and bring to their true value the consequences that may be logically deduced from these experiments.

Finally, we conclude our analytic review with the description of means attempted for the division of the light, and with some consideration of the present state of the question.

We have consulted the following special works, and borrowed from them several interesting notes:—The physical treatises of Messrs. Jamin, Daguin, Ganot, Pouillet; the electrical treatises of Messrs. Becquerel, de la Rive, du Moncel, Jenkin, Guthrie; the treatises on light of Messrs. Tyndall, Becquerel, Moitessier; M. Cazin's 'L'Étincelle Électrique,' M. Niaudet-Breguet's 'Machines Gramme,' M. Figuier's 'Merveilles de la Science,' Abbé Moigno's 'Les Mondes,' M. Leroux' 'Machines Magnéto-Électriques Françaises,' the collection of the 'Comptes Rendus de l'Académie des Sciences,' 'Les Bulletins de la Société d'Encouragement,' and the collections of French and English patents.

Our searches in the collection of French patents have procured some very curious information; we have abstracted thence more than one hundred descriptions of apparatus, of which we have published only a very small part, giving, preferably, favour to practical applications, as the principal object of our labour.

Among these old inventions are a goodly number now represented under other names, and that we have believed to be new. It would be easy to cite more than one patent that is a rejuvenation of old combinations, and of which it may be said, in the words of a certain inventor, "The people of former times had little honesty; they have stolen all my ideas."

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ELECTRIC LIGHTING.

CHAPTER I.

THE VOLTAIC ARC.

Means of obtaining the Electric Light—Voltaic Arc—Despretz' Experiments—Appearance of Two Carbons during their Combustion—Matteucci's Experiment—Le Roux' Comparison—Analogy between Electric Light and Sunlight—Tyndall's Experiments on the Heat developed by the Electric Arc—Use of the Electric Light in Theatres—Lighting of Works by Night—Report by M. Brüll on the Use of Serrin Regulators in Spain.

THERE are two methods of practically obtaining the electric light: the first, which is nearly exclusively the only one known, consists in employing two carbon electrodes, between the extremities of which plays a series of sparks forming a dazzling focus termed the *voltaic arc;* the second is founded upon the incandescence of a carbon rod interposed between two conductors, also in carbon, but of much larger section than the luminous rod.

The electric light may also be produced by the use of Geissler tubes, but the feeble lighting power of these tubes renders them unsuited to domestic or industrial usage. The light resulting from the voltaic arc has the advantage of having been studied by a large number of physicists and of being at the present time in practical use, but it presents the inconvenience of occurring only in an intense focus and of being indivisible above a certain intensity. The light from incandescence admits of obtaining small foci and of greater or less subdivision of the light, but this is obtained only by complicated processes, and

gives only a poor efficiency with regard to the battery power or motive force expended to drive a magneto-electric machine.

As we have it principally in view to make known the industrial applications of the electric light, we shall occupy ourselves specially with the effects observed in the production of the voltaic arc, devoting one chapter only to a description of the trials made and apparatus devised to obtain light by incandescence.

Some previous explanations are necessary for the comprehension of the regulating apparatus to be described.

In approaching one to the other the two conductors of a sufficiently intense electric source until they touch, and subsequently gradually separating them, an extremely brilliant luminous arc appears, which remains so as long as the distance between the conductors is not too great. This arc has received the name of the *voltaic arc*, in honour of the inventor of the battery with which it was produced for the first time.

The brightness of the voltaic arc depends upon the intensity of the current, and upon the nature of the electrodes, and upon the medium in which it is produced. With potassium or sodium, for example, the light is more brilliant than with platinum or gold; in the air there is greater light than in mercurial vapours.

The colour of the arc varies with the substance of the electrodes; it is yellow with sodium, white with zinc, green with silver, &c.

The appearance of the focus depends especially upon the form of the electrodes: between a point of coke positive and a plate of platinum negative it presents the form of a cone; between two carbon points it has the shape of an egg, &c.

The maximum length of the focus depends essentially upon the strength of the current. Davy, who was the first, in 1813, to observe the voltaic arc, found that with 2000 zinc and copper couples, of 2 square décimètres each, a space of 0·11 mètre occurred between the carbon points in air and 0·18 mètre in a vacuum.

Towards 1850 Despretz made a series of experiments on the voltaic arc, and he found: (1) that the length of the arc in-

creased more quickly than the number of elements employed to produce it; (2) that this increase is more pronounced with small arcs than with large. Thus, the arc produced with 100 Bunsen elements is nearly quadruple that produced by 50 elements; that resulting from 200 elements is not triple that from 100; that from 600 elements is about 7½ times greater than that from 100. The battery of 600 elements, coupled in a single series, gives as much as 0·20 mètre of arc when the positive carbon is the higher; (3) that, when the elements are coupled in quantity, the length of the arc increases less quickly than the number of elements. The arc from 100 elements being 0·025 mètre, it is only 0·069 mètre with 600 elements coupled in 6 series of 100, whilst with the same battery of 600 elements coupled in tension it attains 0·183 mètre. Coupling successively in quantity some series of batteries of 25 elements in tension, there is obtained: for a single series, nearly no arc at all; for 2 series, an arc still too small to be measured; for 3 series, 0·001 mètre; and for 24 series, 0·0115 mètre. The same batteries coupled in tension give an arc of 0·162 mètre, that is to say, a space between the carbons 14 times greater than with 24 series coupled in quantity; (4) when the positive pole is the lower one the voltaic arc is shorter than when the negative pole occupies this position. With 6 series of 100 elements coupled in quantity there is obtained 0·074 mètre distance when the positive pole is the higher and 0·056 mètre if it be the lower; (5) that when the electrodes are placed horizontally the arcs are shorter than with verticale lectrodes, and then the battery arranged for quantity is more advantageous than that for tension. Thus, 6 series of 100 elements coupled for quantity give an horizontal arc of 0·040 mètre, and 600 elements, end to end, give only an horizontal arc of 0·027 mètre.

Only Despretz' experiments are sufficiently complete to enable precise conclusions to be drawn, and they well explain the difficulties which constructors of magneto-electric machines have encountered in seeking to obtain the voltaic light with apparatus of great quantity and of low tension.

The voltaic arc results from the incandescence of a jet of

particles detached from the electrodes and projected in all directions. This projection takes place principally from one pole to the other, and more particularly from the positive pole to the negative pole. The positive electrode has a temperature much higher than the other, and whilst the negative carbon is only heated to dull redness at some distance from the arc, the positive carbon is heated to white redness for a considerable length.

FIG. 1. VOLTAIC ARC.

The consumption of the positive electrode for a given time is double that of the negative electrode. It is this difference in consumption and temperature, observed from the beginning by physicists, which later led to the explanation of the luminous arc as a simple transport of particles from the positive pole to the negative pole. At the present time it is thoroughly demonstrated that if the transport from the positive to the negative electrode predominates in the arc, there nevertheless exists a very active transportation of particles from the negative to the positive electrode.

The arc (Fig. 1) resembles a trembling or flickering flame, the form of which is ovoid with the carbon points. From time to time there is to be seen a brilliant particle carried from one electrode to the other, and producing a luminous train. On each of the carbons appear here and there liquid and incandescent globules, *g*, *g*, caused by mineral substances seeking, in a state of fusion, to gain the other electrode.

The liquid globules do not appear when the carbons are chemically pure.

When the voltaic arc is produced in air, the two carbon rods diminish rapidly in volume, because they both burn throughout;

but in a vacuum, this combustion does not occur, and we see the positive point hollowed out and diminished in weight, whilst the negative point elongates and increases in volume. The consumption is nearly *nil*, and results only from some projected particles failing in their reciprocal action.

In truth, the voltaic arc is a portion of the electric circuit, possessing the properties of all other parts of the same circuit. The molecules, swept away from point to point, constitute, between these points, a mobile chain more or less conductive, and more or less heated, according to the intensity of current and the nature and separation of the electrodes. These things happen exactly as if the electrodes were united by a metallic wire or carbon rod of small section; which is but saying that the light produced by the voltaic arc and that obtained by incandescence arise from the same cause, that is, the heating of a resistant substance interposed in the circuit.

Matteucci, a celebrated Italian physicist, has demonstrated this parallel relation between the voltaic arc and other parts of the electric circuit, by slowly separating two cones of iron previously put in contact: a fibre of liquid metal appears, becomes luminous, breaks up, and takes the form of the voltaic arc.

Among the scientific men who have occupied their time with the study of the properties of the electric arc may be cited: Messrs. Wheatstone, De la Rive, Becquerel, Grove, Favre, Quet, Neef, Sillimann, Van Breda, Despretz, Matteucci, Foucault, Fizeau, Tyndall, Le Roux, Cozin, &c., of whose memoirs all know. These works are more scientific than practical; but we would call the attention of persons to these before they attempt, on their part, further new researches.

At a meeting of the *Société d'Encouragement*, M. Le Roux has well characterised the phenomena of transformation which occurs in the production of the arc; and he has insisted on the point that the voltaic arc is formed only by a true vapour of carbon.

The electric light, indeed, owes its special properties to the condensation of a great quantity of heat in a very limited space. This heat is taken from the combustion of zinc in a battery, or from the furnace of the steam engine, which puts into motion the magneto-electric apparatus; theoretically, the difference should

be small—practically, only a very small part is reclaimed. In practice, it is necessary to take into account a host of circumstances, of which theory takes no notice. Besides, the question is not that of knowing if we use well all the heat of the coal burnt in the steam-generator, but by what other means we could condense as great quantity of light into as limited space, and from this point of view the voltaic arc leaves far behind all other methods of production.

To condense heat in a limited space, so as to raise to great intensity the temperature of the substance, such is the proposition of the problem of the production of the electric light. In the combustion of a substance, that is to say, in its combination with oxygen, for the same quantity of the substance burnt there is always produced the same quantity of heat, as the oxygen may be taken pure or from the air, but the temperature is much less with atmospheric oxygen than with pure oxygen.

Electricity is the best known means for condensing the greatest possible quantity of heat into a limited space, and it, besides, affords the greatest facilities in the transport of this heat to a given point.*

The electric light has great analogy, as to effects produced, with the light of the sun. It brings about the combination of chlorine with hydrogen, it discolours chloride of silver, it imparts phosphorescent properties, that is to say, renders luminous in the dark those substances which become so under the action of solar rays. These valuable properties have been utilised in photography, and in several industries where it is necessary to distinguish colours correctly during the night.

By intercomparison of several luminous sources, Foucault and Fizeau have found that the light of the voltaic arc attains half that we receive from the sun on a very clear day, whereas the Drummond light is only equal to a hundred-and-fiftieth of this, and the moon's light to not more than the three-hundred-thousandth part. As to the sun itself, it imparts to a given surface the brilliancy of 5774 candles placed at 0·33 mètre distance. The stars yield to our globe only a very insignificant

* 'Les Machines Magneto-Electriques Françaises.' By F. P. Le Roux. Gauthier-Villars. 1868. P. 43.

light: Sirius, one of the most brilliant, has a brightness not exceeding the seven-hundredth part of that of the moon; five thousand million such stars would scarcely afford a light equal to that of the sun.* Although the electric light heats a room infinitely less than gas for equal luminous intensity, the electric arc is the seat of an extremely elevated temperature. Substances reputed the most refractory are there consumed with extraordinary rapidity.

Professor Tyndall has made some very beautiful public experiments on the heat developed by the voltaic arc; and to further interest his audience, he rendered the light rays emitted by the carbon points invisible. For this purpose, Dr. Tyndall concentrated, by reflection, from the surface of a small silvered mirror, the rays from the luminous focus, and he interposed in the convergent cone of light thus obtained a glass vessel containing an opaque solution of iodine. The cone of light is completely destroyed; but radiation of heat subsists, and, converging to an invisible focus, produces the most curious effects.

Thus, when there is placed in this focus a small piece of black paper, it is pierced by the rays as if it had been traversed by a bar heated to whiteness. The paper instantly ignited. A heap of wood and of chips takes fire as soon as placed in the focus. A cigar is quickly ignited. A piece of wood-charcoal, suspended in a receiver filled with oxygen, takes fire in the focus and burns with the brilliancy that this substance does in an atmosphere of oxygen. The invisible rays, even after traversing the receiver, still preserve sufficient power to heat to white-redness. A mixture of oxygen and hydrogen explodes at the dark focus by

* Account is here taken of the emissive power per square mètre of the lighting body and not of the total light developed. Arago found that solar light was four or five times more intense than that of the voltaic arc. The difference between the results of Fizeau and Foucault and those of Arago it is easy to explain by simply considering that even if we can calculate the diameter of the sun and its distance from the earth with sufficient approximation we cannot do so with the lighting surface of the voltaic arc. The luminous focus does not present a spherical form, and each part of the surface emits rays of extremely variable intensity. The electric light was produced by rather powerful voltaic batteries, but its brilliancy was incomparably less than that realised with some machines. If the experiments were repeated with powerful Gramme machines it would probably be found that the voltaic arc has the same emissive power as the sun.

mere heating of their containing vessel. A band of blackened zinc, placed at the focus, is pierced and ignited by the invisible rays. Passing the band gradually across the focus, this may be maintained in full brilliancy for a considerable time, with the characteristic purple light. This experiment is peculiarly beautiful. A magnesium wire burns at the focus, with nearly intolerable brilliancy. A thin carbon plate, placed in a vacuum, is raised to incandescence by the invisible rays. Dr. Tyndall has obtained still more astonishing effects, which it would take too long time merely to name. The following are the most characteristic: With a battery of sufficient power, and the requisite concentration, he has heated to whiteness a plate of platinum, and this viewed through a prism presents a brilliant complete spectrum.* As there has not been at disposal a mechanical generator of electricity, the use of the voltaic arc has been limited to laboratory experiments, to the illumination of public fêtes, theatrical scenic effects, and very urgent night works, until the present day when, thanks to the discovery of the Gramme machine, it has begun to enter into the service of a large number of industries, and the successes of the first introduction lead to the hope that it will develope itself very rapidly.

It was in 1846, in the *Prophète*, that the electric light made its *début* at the Opera in Paris. It was employed to produce the effect of the rising sun. The success was so complete that it was saluted with unanimous applause, and since that time it is rarely that a ballet or an opera has been mounted without the introduction of some effect of the electric light.

The voltaic arc has not been applied only at the theatre to project a vivid light on certain points of the scene, to illuminate subjects, decorations, groups, &c. Its intense rays are used to reproduce physical phenomena and fantastic apparitions.

Mr. Duboscq, in charge of the electrical service at the Opera since 1855, has realised a host of ingenious combinations. To him is due the magnificent effects of the rainbow, lightning, the reflection from windows lighted by the sun, luminous fountains, &c. The most beautiful of these effects, the rainbow, is obtained

* These remarkable experiments were made at the Royal Institution, 27th January, 1865.

by several lenses and a prism: the first lenses give a parallel beam, which is passed through a screen cut in the form of an arc; this beam is received by a biconvex lens of very short focus, which increases the curvature of the image, and considerably magnifies it. Issuing from this last lens the ray impinges upon the prism and is decomposed into the rainbow.

At the New Opera at Paris batteries are used, because the architect did not wish to locate a steam-motor in any part of the edifice, and the machines for producing electricity cannot be used

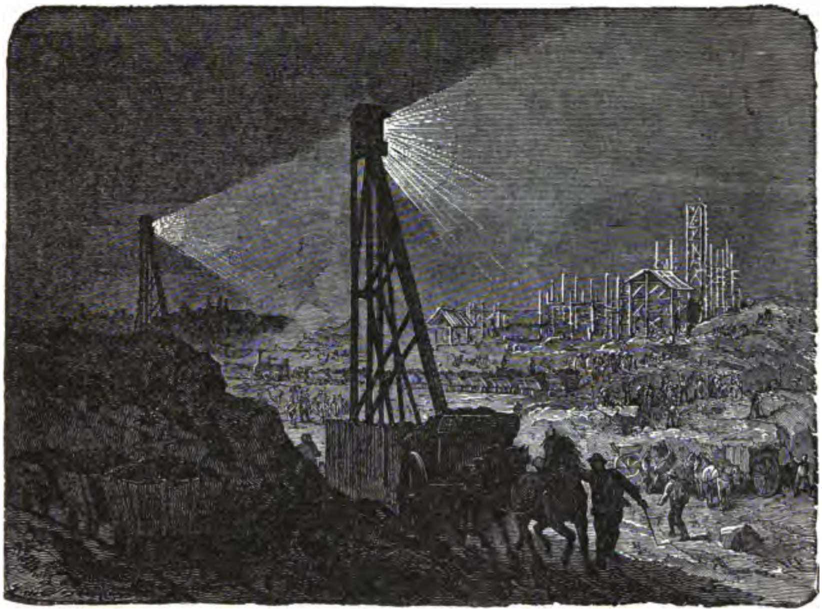

FIG. 2. ILLUMINATING A DOCKYARD IN COURSE OF CONSTRUCTION.

without a motor. At the Opera in Vienna, where steam is employed throughout, use is made of a Gramme machine, which gives very good results.

Of the lighting for public fêtes we have nothing to say that would be important from an industrial point of view, and the devices for this use are too well known as to their limited value in the decoration of an open place, an avenue, or a monument. The lighting of works by night (Fig. 2) is much more in-

teresting. In this matter there is nothing more conclusive in favour of the electric light than the following report, made by Mr. Brüll, Vice-President of the Society of Civil Engineers.

"The Spanish Northern Railway Company, . . . at the commencement of the month of April, 1862, made a series of trials with regulators (lamps) of the Serrin Electric Light System. The results being satisfactory, twenty regulators were purchased, and sent, with the requisite batteries, to the Guadarama mountains. . . . The first actual introduction was in the month of March, 1862; in July eight lamps were in use, and the light was regularly employed until October 15th. To this time the light had been in use 3717 hours. . . . After three months' interruption, caused by excessive cold, night-work was recommenced in 1863, and ten electric lights were in use until June 12th, when the works were finished. The total duration of these two periods was 9417 hours. The light was always good and regular, it properly lighted the yards, without injury to the labourers by its intensity. Two kinds of reflectors were employed, hyperbolic and parabolic; hyperbolic reflectors were preferred. The expense per hour for material consumed was 2·90 francs per lamp. The economy realised by the application of the electric light was 60 per cent. upon the use of torches. If, besides, there is considered the inconveniences caused by the fumes of the torches concentrated in the deep trenches filled with labourers, the loss of time in maintaining the combustion, and the feeble light, the superiority of the electric light is incontestable. The fear of producing, for equal times, less work during the night than during the day is unfounded. In summer, the workman, not oppressed by the heat of the day, labours with greater energy and produces with greater advantage; during cold nights he works to warm himself; in any case, night service is not inferior to day service.

"Electric lighting has rendered important services to the subterranean works of the great mines of Guadarama. The depth of the pits was 22 mètres, the length of each gallery 16 mètres, . . . the air was so vitiated by the explosion of charges and the combustion of the miners' lamps, that the masons could not remain longer than a few moments; the lamps would not burn in

the interior of the mine; lighted at the surface of the pits, they were extinguished before arriving at the bottom. The work was pressing; there were no other means of ventilation to hand; I sent down a Serrin regulator into the interior of the mine. . . . At the end of an hour, seeing that the masons did not complain of inconvenience nor demand to be relieved, I descended into the mine, and I state that respiration there was as easy as in open air, and that the lamps remained alight. The mason-work, by the electric light was prolonged for 112 consecutive hours without inconvenience."

We may still cite, amongst open-air works executed by the aid of the electric light, those of Fort Chavagnac at Cherbourg, of the Railway *du Midi*, the reservoirs of Ménilmontant, the building for the *Moniteur universel*, and, more recently, those of the Havre harbour and docks, the Exhibition of 1878 in the Trocadéro, the Opera House Avenue, the Grands Magasius du Louvre, &c., &c. In chapters VII. and VIII. precise details are given of a larger number of applications to private industry, lighthouses, the navy, and war purposes.

CHAPTER II.

ELECTRIC LAMPS, OR REGULATORS.

Inutility of Researches as to Regulators — Deleuil's Experiments — Wright's Apparatus — Staite and Edwards' Regulator — Le Molt's Regulator — Archereau's Regulator — Lacassagne and Thiers' Regulator — Gaiffe's Regulator — Foucault and Duboscq's Regulator — Way's Regulator — Alteneck's Regulator — Serrin's Regulator — Girouard's Regulator — Carré's Regulator — Jablochkoff's Inventions.

The increasing success of electric lighting in industrial establishments has given a fresh impulse to the labours of electricians, and many have specially directed their attention to the regulating of the light, that is, to the problem consisting in maintaining constant the distance of the two carbons between which the voltaic arc is playing.

As the majority of inventors have but slight acquaintance with the question, and ignore previous labours, nearly all their researches tend towards old combinations long since abandoned, or to original but impracticable ideas. To avoid the recurrence of similar labours, which always occasion considerable loss of time and money, we describe a rather large number of regulators of different types.

We must not say, off-hand, that present researches have no absolute utility, for there exists one good regulator, that of M. Serrin. This apparatus works with precision, and gives a steady light, under the sole condition of being furnished with good carbons, and fed from a constant source of electricity. However, we wish to discourage none, and we do not say that M. Serrin's regulator is the best that may be devised, but we find it so superior to all that have come before us, that we solicit inventors to study it well before torturing their imaginations to replace it. There may, perhaps, be found a slightly more simple and less expensive apparatus, but it will be difficult to find one more compact and easy to use.

In our opinion, a new invention, even possessing all the properties requisite for the most varied applications, and none of the defects so frequently found in regulators, can, from the point of view of propagating electric lighting, have only secondary importance, unless its selling price is very low and its construction extremely simple.

Until 1844, experiments with the voltaic arc had no utilisable result: the absence of carbons and convenient batteries limited

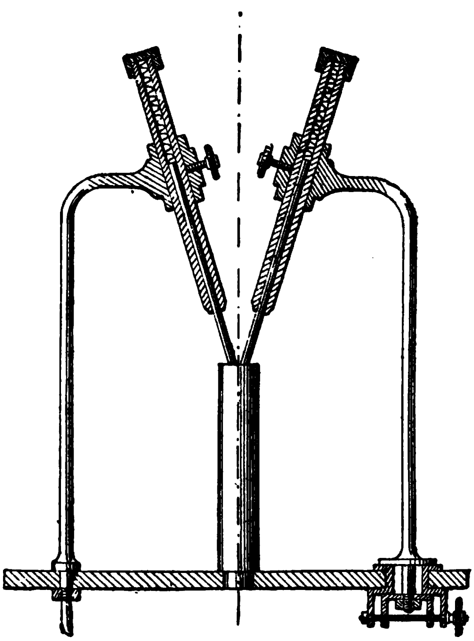

FIG. 3. STAITE AND EDWARDS' REGULATOR.

the duration of the phenomenon to the time strictly necessary for its appreciation in a lecture on physics, but no one dreamt of its practical use. At this time, Léon Foucault, in endeavouring to put to profit the powerful battery combined by Bunsen, hit upon the happy idea of substituting rods of carbon, taken from gas retorts, for the wood carbon rods generally employed as electrodes. This able physicist constructed a small and very

simple lamp, and substituted for the sun the voltaic arc for obtaining photographic proofs.

This first lamp, the use of which needed help from the hand of the operator, enabled M. Deleuil to make some trials in electric lighting, during the same year, 1844, at the Place de la Concorde, Paris (M. Deleuil had already made public trials in 1844 with ordinary carbons placed in a receiver from which the air was exhausted).

In 1845, Thomas Wright, of London, endeavoured to cause the voltaic arc to play between discs of carbon having their circumference cut to a V-shape, and receiving motion from well-known mechanism. This was the first automatic regulator, and the origin of Le Molt's apparatus, which is described subsequently.

In 1846, Staite and William Edwards, of London, patented several original arrangements, one of which is represented in Fig. 3. The two electrodes of carbon are enclosed in small cases, and meet obliquely on a substance resistant to heat and nonconductive of electricity. Springs bring the points to their place as they are consumed. By means of a sliding-piece and screw placed beneath the baseboard, the carbons may be brought together or withdrawn, and the length of the voltaic arc consequently varied.

In 1848, Foucault in France, Staite and Petrie in England, devised the use of the current itself to regulate the distancing of the carbons, and based their idea upon the two phenomena: (1) that an electric current can give rise to magnetisation in soft iron surrounded with copper wire, which is weakened and disappears as the current diminishes or becomes nil; (2) that the voltaic arc, being a portion of the conductor, reacts on the current by reserving to it a great part of its intensity for a given distance, and completely destroying it when the distance between the carbons becomes too great.

In 1849, Le Molt took up Thomas Wright's idea, and constructed the apparatus represented in Fig. 4, which is thus described in the French patent:—

"As electrodes producing the light, I patent the use of all carburised matter, especially that of retort carbons, and the two

combined movements of rotation and approximation at given intervals of two discs of variable depth and diameter.

"The rundles are maintained, with regard one to another, in a parallel attitude, vertical or horizontal, or, better, in positions at right angles, and conveniently distanced one from the other, to produce the electric light. They revolve in a regular manner upon two metallic axes put into connection with the poles of the generating apparatus, and presenting, successively, by the combined rotation and approximation, all the extreme points of their circumferences to the production and emission of the electric light; in such manner that at each revolution of the discs, the latter approach one another by the distance which they had separated by the combustion of part of the carbon, and thus are always replaced in the same position of invariable distance; and as the two movements of rotation and approximation, combined with revolving electrodes, may be obtained with the aid of any kind of mechanical system, it is sufficient that I indicate in my design one of these arrangements, to illustrate how the rotation and approximation may be combined.

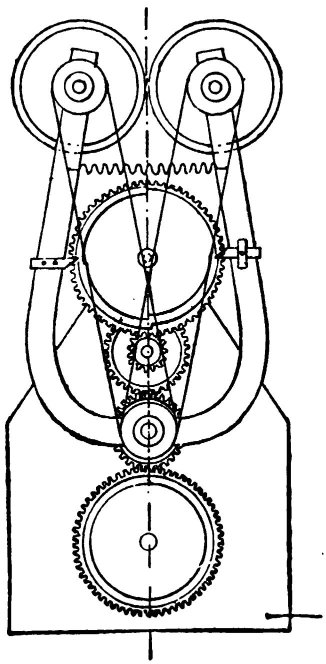

FIG. 4. LE MOLT'S REGULATOR.

"I reserve to myself the purification of carburised matter forming the electrodes emitting the light, by more or less prolonged immersion in all kinds of acids, and preferably in nitric and muriatic acids mixed, and subsequently in fluoric acid."

This arrangement is very interesting, in that it admits of working twenty to thirty hours without touching the lamp,

but it gives a less intense light than that obtained with two vertical bars of carbon. The Railway Company *du Nord* have recently made trials with a similar apparatus, and have obtained very good results.

The best known apparatus, founded on the use of magnetism, for the regulating of the carbons, are those of Archereau, Lacassagne and Thiers, Gaiffe, Foucault and Duboscq, Hefner-Alteneck, and Serrin. Although the first two are no longer in use, they are interesting, and we describe them succinctly.

Archereau's Regulator.

The Archereau regulator, represented in Fig. 5, is the most simple of all. It consists of a hollow copper bobbin, coiled with insulated wire, a vertical standard, two carbon-carriers, and a counterweight. The upper carbon is carried by a bar which slides into and turns at the extremity of a horizontal copper bar, insulated and in communication with the negative conductor of the electric current. The lower carbon rests on a cylinder, half of copper half of iron, which can rise or fall in the hollow bobbin. The positive conductor is attached to one of the extremities of the wire on the bobbin, and the other extremity of this wire is fixed to the interior cylinder of the bobbin. The lower carbon is in direct communication with the positive pole, because the cylinder which carries it touches at several points the cylinder of the bobbin. A counterpoise equilibrates the lower carbon-carrier in such a manner that its movement, in either upward or downward direction, may be effected with insignificant effort. (To disturb equilibrium, it is sufficient to overcome the friction of the cylinder against the interior sides of the bobbin.)

The upper part of the cylinder is of iron, the lower part of copper. When the current passes in the exterior wire, it produces a magnetic action which causes the cylinder to descend in the bobbin, and as the current is thus interrupted, the action of the counter weight raises the cylinder.

To put the apparatus in action, it suffices to bring the upper carbon into contact with the other, and then to slightly separate

them; the voltaic arc is formed, the cylinder remains fixed in the bobbin, and the counterweight is motionless. This arrangement is maintained whilst the distance of the carbons is not too great; but the voltaic arc soon surpasses a given length, and the current is too feeble to cause the cylinder to resist the action of the counterweight. At this instant the lower carbon rises, when the current again attains sufficient power, and stops the cylinder until fresh consumption leads to another movement of the lower carbon. It is a simple question of balance, to be realised by proper proportion of the several parts and by the exact determination of their relative positions.

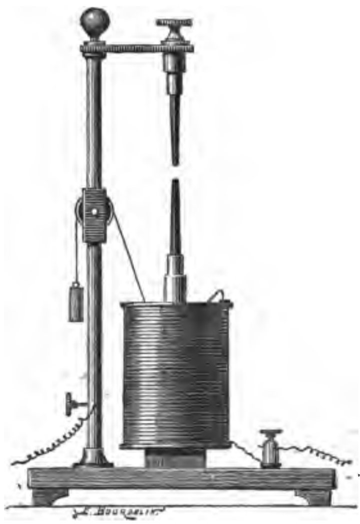

FIG. 5. ARCHEREAU'S REGULATOR.

The Archereau regulator differs from those of Foucault and Staite, in so far that it possesses a solenoid in the place of an electro-magnet, to ensure constant distance between the two carbon points.

LACASSAGNE AND THIERS' REGULATOR.

The regulators following those of Foucault and Archereau all possess clockwork mechanism for the approximation of the electrodes, and an electric brake or detent for stopping the mechanism at the proper time. Messrs. Lacassagne and Thiers having observed several inconveniences in the use of clockwork movements, replaced them by a float acting in a bath of mercury. This regulator was patented in 1855.

The receiving cylinder contained a float upon and in connection with the metallic bath; this float is surmounted by a carbon electrode; it is in connection with the positive conductor, and in relation to another carbon electrode, fixed at the upper part of

the lamp. The float should rise whenever the distance of the related points increases by the effects of combustion. It will be subsequently perceived that it is to the displacement of mercury that this effect is due; but in order that this displacement may occur at the proper time, a special arrangement, put in play by the electric current itself, is devised to regulate it.

Mercury from a reservoir, having entered the receiving cylinder, traverses through a tube one of the branches of an electro-magnet, interposed in the circuit and making part of the lamp; to this tube is adjusted a small india-rubber valve, opened and closed by an armature of soft iron, drawn back by a spring antagonistic to the attraction of the electro-magnet in the lamp; the opening of this valve admits of the passage of the mercury, and its closure retains the mercury in the reservoir. Whenever the interpolar distance augments, the magnetic action diminishes, and the armature yields to the action of the opposing spring (previously tightened more or less, according to the intensity of the current); the valve opens and admits of the entrance of mercury, which then raises the float, and consequently brings the points to their focal distance; after which the magnetic attraction, increasing in inverse ratio with that distance, closes the valve, and *vice versâ*.

The sensitiveness of this arrangement is such that, as the armature operates to open the passage to the mercury from the receiver in order to cause the rise of the electrode that the float supports, this rise, instead of occurring in jerks, is regulated by two opposing forces, which balance in such a manner as to allow the passage of a small continuous jet of mercury into the receiver, in accurate proportion to the consumption of the carbons in a given time. The electrodes thus continually approximate.

From 1855 to 1859 the inventors of this apparatus made numerous attempts at lighting in Paris and Lyons, but although their regulator worked steadily, they obtained only the success that arises from curiosity. This result, more negative than favourable, came about from several causes: the use of batteries, as generators of the electric current, is fertile in inconveniences; then the necessity of bringing constantly the voltaic arc to the focus of the reflector (the upper carbon being consumed and not

movable, it is evident that the luminous focus varies constantly). On the other hand, the use of mercury in substitution for clockwork mechanism was not adaptable to industrial purposes. In spite of this, these experiments made great noise, and we have before us a volume devoted to their praise. The following extract appeared in the 'Gazette de France,' July 5th, 1855, twenty-two years ago:

"Yesterday, those who were walking at nine o'clock in the evening in the neighbourhood of the Château Beaujon were surrounded by waves of light as powerful as those of the sun. Indeed, it might have been said that the sun had again risen, and so great was the illusion, that the birds, surprised in their sleep, fluttered about in this artificial day. The luminous focus appeared from the terrace of the Château Beaujon, where Messrs. Lacassagne and Thiers, chemists of Lyons, showed before a select company, brought together by M. Théodore Gudin, the advantages of the electric light as apart from theory, and as having entered the domain of accomplished facts. The trial was perfect. The power of the luminous focus, embracing a vast surface, was so refulgent that the ladies invited opened their parasols, not in gallantry to the inventors, but to shield themselves from the ardour of this mysterious and new sun."

These last lines contain, in reality, one of the most just criticisms that have ever been addressed to the electric light; the rays projected by a reflector are so dazzling that if the electric light could not be used without a reflector, its employment could never have been extended to manufactures.

The power of the light that was at that time compared to a mysterious sun, was that only of some 60 to 80 Carcel burners. What would the 'Gazette de France' have said if the Lacassagne and Thiers lamp had burnt with a brilliancy equal to 4500 burners, as the Serrin lamp burns when fed by a single Gramme machine?

Gaiffe's Regulator.

Gaiffe's regulator is represented in Fig. 6.* The following

* This Figure, and the description of the Gaiffe regulator, are reprinted from the excellent work by M. Figuier, 'Les Merveilles de la Science.' Furne,

description will explain the use and working of each part. A B C D is a cylindrical case enclosing all the mechanism. It consists of a circular plate A B connected to a base or truncated conical foot C D by four bars or vertical columns. A cover F, removed by lifting, encloses all, and is fixed into the plate A B by two screws G, placed at the extremities of the same diameter.

H, upper carbon-carrier, formed of two shells, between which the graphite pencil is pinched. H′, lower carbon-carrier, arranged like the former.

I, racked cylindrical copper bar, commanding the carbon-carrier H, and its movement in the interior of a hollow column J, fixed vertically on the plate A B. This bar is terminated at the lower end by a stop-piece mounted at right angles, and intended to limit its ascending course.

I, racked soft iron bar furnished with stop-piece, and commanding the carbon-carrier H′. This bar is in the shape of a quadrangular prism, and descends vertically into the interior of the bobbin *l*.

l, bobbin with axis vertical, carrying a copper wire, wound helically. When the electric circuit is closed, this acts upon the bar K, which then descends by virtue of the attraction to which it is submitted.

O, two tooth-wheels, burning freely on the axle N, and insulated from each other by an ivory disc. The diameters of these wheels are in the ratio of 2 to 1. The larger engages with the rack upon the bar I, the movement of which it commands, and the smaller engages with the rack upon the bar K; consequently when the bar K is raised or lowered to a certain extent, the bar I is raised or lowered to double this extent. This arrangement is necessitated by the unequal consumption of the two carbons, which with the battery is in the proportion of 2 to 1.

A barrel, fixed to the wheels O, contains a clock-spring, one end of which is fixed to the barrel itself, and the other to the axle N; this spring acting on the barrel, and consequently on the

Jouvet, and Co., publishers. Vol. iv., p. 225. Figures 2 and 17 are also taken from the same work.

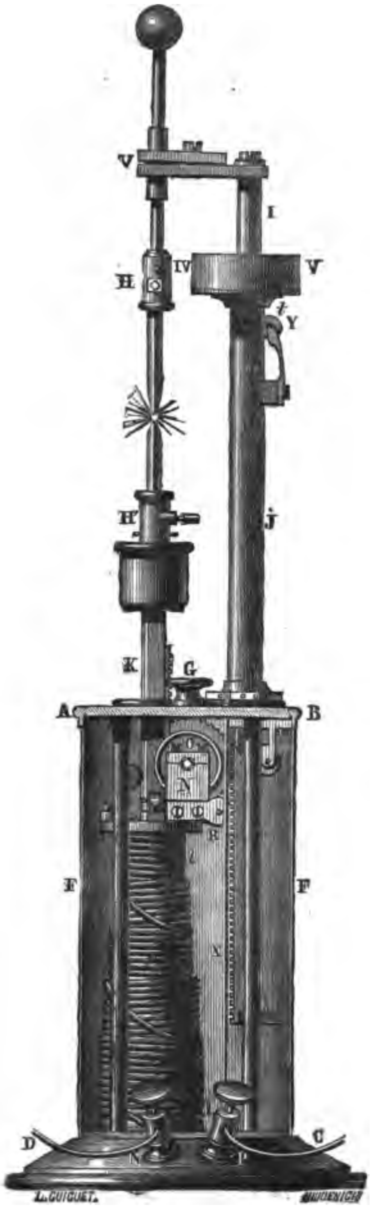

FIG. 6. GAIFFE'S REGULATOR.

tooth-wheels, tends constantly to approximate the bars I, K, and consequently the carbons.

N, steel axle, on which the wheels O and the barrel are freely mounted. This axis is grasped between bearings, which, however, permit of its revolving, for the regulation of the barrel-spring; for this, one end of the axle is squared, where a key may be used. A circular base receives the coil *l*. On this bobbin, which is pierced at the centre to allow for passage of the bar K, are mounted the principal pieces of mechanism. The pinions R are mounted on an axle parallel to the axle N, and these may be displaced parallel to themselves, in order to command the wheels O, and consequently act on the bars I, K, to raise or lower at will and simultaneously the two carbons, in optical experiments where it is important to centre the luminous point without interrupting the working of the apparatus.

A square-holed key may be set upon the axle N, or on the axle of the pinions R, when it is wished to affect the barrel-spring, or when it is wished to put the pinions in connection with the wheels O. A bent spring placed on the axle of the pinions R, serves to return these pinions to their place when no longer under adjustment. Friction-wheels guide the bars I, K, rendering their movement very even.

V is an adjusting clamp acting directly on the carbon-carrier H, so as to put the carbon points exactly in line with each other.

N is the terminal for the negative conductor of the electric current.

P is the terminal for the positive conductor of the electric current.

X is a vertical bar leading the current from the terminal P to the column J.

Y is a guide-wheel entering by an opening into the column J, and maintained constantly in contact with the bar I, by means of a spring, so as to ensure communication between this column and bar. The terminals N, P, the bar X, and the column J, are insulated with india-rubber discs.

The current passes in the different parts of the apparatus as follows: entering by the terminal P, it passes through X, J, I,

V, H, H', K, through the coil *l*, and issues by the terminal N. When it does not circulate, the two carbons are maintained in contact with each other by the action of the barrel-spring; but as soon as the electric circuit is closed, the coil attracts the bar K, the movement of which, combined with that of the other bar J, determines the distance of the carbons and the production of the voltaic arc.

In order that this action may take place, it is necessary that the attractive force of the bobbin is slightly biased in favour of the barrel-spring. When the spring is too taut, the two carbons remain drawn one against the other, or are brought too near together to produce a light of sufficient intensity; if, on the contrary, it is not taut enough, the action of the bobbin becomes too predominant, and consequently, the distance between the carbons being too great, the voltaic arc is interrupted.

Foucault and Duboscq's Regulator.

Foucault's regulator, made and perfected by Duboscq, has a high reputation; it has our preference next to M. Serrin's apparatus. It is represented in longitudinal section, Fig. 7.

The electro-magnet is placed in the lower part of the apparatus. Like all electro-magnets, it consists of a bobbin on which is wound a long copper wire. By traversing this wire, the current magnetises an iron cylinder forming the core of the bobbin, and this attracts a plate of the same metal screwed to the extremity of a bent lever. A spiral spring parallel to the electro-magnet balances the magnetic attraction, so that the contact is not called into operation except when the current has a given strength. The opposing spring, as may be seen, is fixed at one of its ends to a small oscillating jockey-lever, which admits of rendering it more or less taut, and consequently the lamp more or less sensitive.

Above the electro-magnet is a box enclosing a clockwork movement actuating, as required, the bars of two carbon-carriers, which are racked and engage with wheels of different diameters, as in the preceding lamp. An oscillating bar connects the armature to this clockwork mechanism, and acts as detent to

an escapement arresting movement of the clockwork when the voltaic arc is neither too large nor too small—that is, when the current passes regularly in the apparatus. When the arc becomes too long in consequence of the consumption of the carbons, its resistance increases, the armature is drawn against the electro-magnet, and the detent liberates the clockwork.

In M. Duboscq's original apparatus it was necessary to separate the carbons by hand in order to regulate their position and their distance; Foucault has added a second clockwork mechanism, which separates the carbons as required.

This auxiliary mechanism, like the first, acts upon the wheels which engage with the racked bars of the carbon-carriers, only its movement is inverted.

There are then in this regulator two distinct motors, one to separate the carbons when they are too close together, the other to bring the carbons together when they are too widely separated. The difficulty, which was to make these two motors independent and to cause them to act oppositely on the same toothed wheels, has been overcome in the happiest manner, by the use of a sun-and-planet motion. The bar that connects the electro-magnet with the two mechanisms oscillates to the right or to the left, and sets free each escapement at the same time; when it is vertical the two escapements are under detent, and no movement is produced. The springs should be wound up before each operation.

With the Foucault-Duboscq lamp the luminous point may be raised or lowered during working, by turning by hand one of the tooth-wheels of the principal barrel. This operation is sometimes necessary when projecting the light for scientific purposes, but in industrial illumination it is without practical utility.

As a whole, this apparatus is very ingeniously combined, and it possesses the advantage that it may be used in all positions, but it is somewhat delicate, needs regulation for every special application, and is slightly more susceptible to derangement than that of M. Serrin. It has extensive use in laboratories and in theatres.

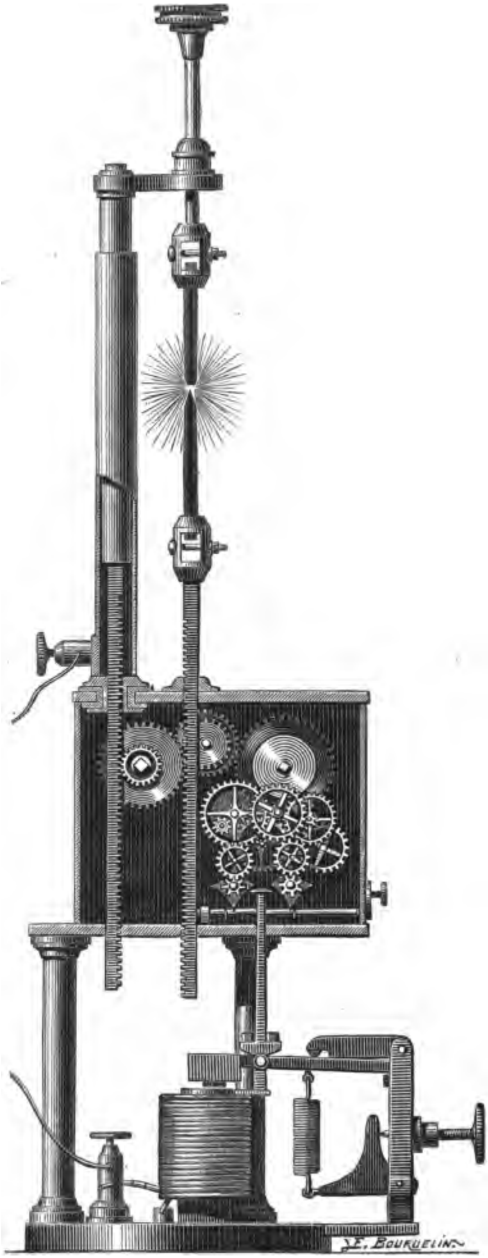

FIG. 7. DUBOSCQ'S REGULATOR.

Way's Regulator.

The regulator invented in 1856, by the English Professor Way, is based on a principle essentially different from that of Foucault. In this apparatus the carbons were replaced by a fine stream of mercury issuing from a small funnel, and received in an iron capsule also containing mercury.

The two poles of the electric generator were put into communication, one with the funnel, the other with the capsule, and there was produced between the successive globules of the discontinuous vein a series of voltaic arcs, and thus a regular lighting focus obtained. The luminous liquid vein was placed in a glass chimney of limited diameter, so that this might become heated, and thus the condensation of the mercurial vapour upon the sides prevented; and as the combustion was carried on out of contact with oxygen, the mercury was not oxidised.

Mr. Way has modified this first arrangement, and has obtained a better light by employing: (1) two outflow electrodes instead of one, so that two currents of mercury, each connected with one of the poles of the battery, falling from the two jets, are carried away by a pipe; (2) by making and breaking the electric circuit very rapidly by means of a small motor worked by the battery, and actuating a mercurial pump.

In spite of all precautions, the apparatus allowed of the escape of very dangerous mercurial vapours, which finally killed the inventor. The light produced by this means was never very intense, and attained only a third of that given by the same electric current between two carbon points.

Alteneck's Regulator.

The Hefner-Alteneck regulator, constructed by Messrs. Siemens and Halske, of Berlin, is much used in Prussia. The position of the carbons in this apparatus (Fig. 8) is regulated, as in the Serrin apparatus, by the weight of the upper carbon-holder, which tends to bring the carbons together as these are

consumed, the electric current actuating a small electro-magnetic motor to separate them.

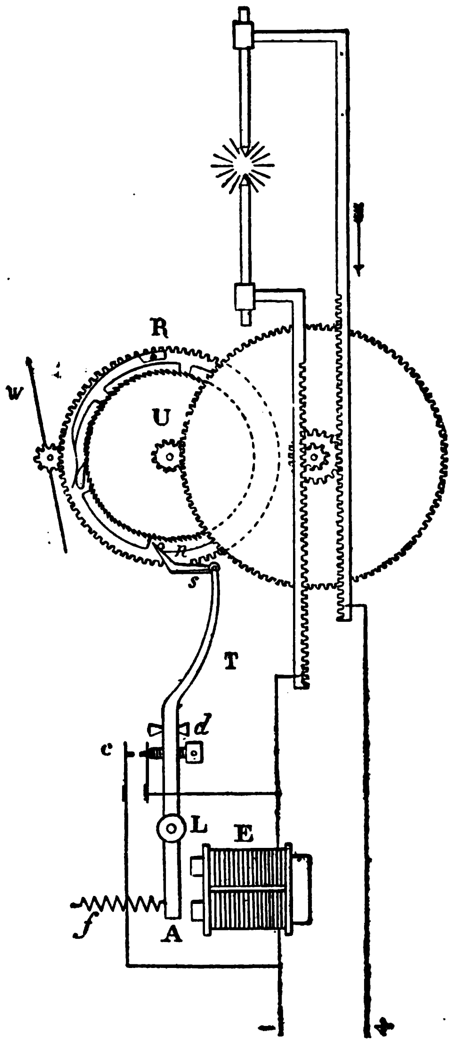

FIG. 8. ALTENECK'S REGULATOR.

The upper carrier, which may be freely moved up and down, is connected to the lower carbon-holder by the intervention of rackwork and a tooth-wheel.

When the approximation of the two carbon poles increases too greatly the intensity of the current, the horse-shoe electro-magnet E attracts the armature A, held back by the spring *f* of variable tension; the latter keeps the bar T, centered at L, against the stop *d*.

When the electro-magnet, overcoming the effort of the spring, has attracted the armature, contact is established at C; as soon as the current ceases to traverse the wire of the motor, the armature reassumes its initial position, and the currents again become direct. The oscillations of the bar T communicate, by means of a small pawl *s*, a rotary movement to a fine-toothed wheel U, which, by the intervention of the train and racks, separates the carbons.

A fixed point *n*, against which the pawl strikes when the armature reassumes its normal position, compels this to leave the teeth of the ratchet-wheel, and allows free access to the racks.

The velocity of approximation of the carbons is regulated by a fly W, put in movement by the train R, commanded by a ratchet-stop, which is not carried forward by the wheel U, when the pawl *s* is in action.

When this regulator is employed with an apparatus giving alternate currents, the motor E works in the same manner, with the difference that oscillations of the armature are produced, without the help of the contact *c*, by the mere change of polarity. To obtain a constant length of luminous arc, the velocity of approximation of the carbons should be made proportional to their consumption, which varies in the ratio of 1 to 2, as the current may be alternating or continuous. A button placed outside the lamp admits of engaging the racks with one pinion or with two toothed wheels, the diameters of which are related as 1 to 2.

This new regulator, independently of its use for continuous or for alternate currents, is distinguished by the regularity of its working. This precision is obtained principally by the use of a single point of support for the armature, instead of two, each corresponding to the period of attraction and to the period of release. Further, there are no clockwork springs in its con-

struction; and the contact has not to be frequently renewed, because only feeble sparks are produced.

Serrin's Regulator.

In order to produce the electric light between the two carbon points of the lamp or regulator, it is necessary, primarily, to put the points in contact, in order that the electric current may be established; then the points must be separated by a slight distance, and these must also constantly approximate in measure as they are consumed by combustion or electric transmission, in such a manner that the luminous focus occupies always the same point in space.

The regulator devised by M. Serrin completely satisfies these three conditions. It leaves the carbons in contact when the current does not circulate, it separates them to the distance required when the current is established; it constantly brings them together without actually making contact. If, by accident, the carbons break or separate too far, they are automatically brought, after an instantaneous contact, to the distance necessary to develope the voltaic arc in all its brilliancy.

Other regulators fulfil the same conditions; but the Serrin regulator gives greater precision, sensitiveness, and less inconvenience.

The apparatus is represented in Fig. 9. It consists of an electro-magnet A, a bar B serving as motor, a bar C carrying the negative carbon, an armature D, an abutment E, a spring F, an excentric G, the positive carbon-holder H, a fixed tie-piece I, an adjustable tie-piece J, a tension lever K L, a double parallelogram M N P Q, a clockwork movement O, adjusting screws R and S, a clamp-screw T, an ivory stop V, which serves to arrest the motion of the lamp, of a copper cover, and a series of accessory details.

The carbons are fixed by means of a press-screw in the two carbon-carriers. The positive carbon is held above the negative carbon by means of a massive cylindrical bar, furnished at its upper end with two horizontal pieces connected to the carbon-carrier. The upper traverse or tie-piece permits, by means of

an adjusting screw, of imparting to the carbon-holder displacement in a plane parallel to that of the engraving. The lower traverse, by means of an excentric commanded by a button G, displaces the carbon in a plane perpendicular to the plane of the figure. The combination of these two rectangular movements gives the means of accurately adjusting together the two points of the carbons. Between these plays the voltaic arc, constantly kept at the height of a small circular gauge mounted on the bar of the positive carbon-holder.

As to the negative carbon-holder, placed beneath the other, this is introduced into a hollow tube, whence it can be withdrawn, to free it from the fragments of carbon that may accidentally be detached. A press-screw holds the carbon in its case.

The following paragraphs describe how the approximation of the points, and their maintenance at a convenient distance, are effected.

1. *Approximation.*—The solid bar of the positive carbon-holder tends to descend vertically under the action of its weight. It is, at its lower end, racked, and, during the descent, engages with a toothed wheel O, which communicates motion to the train, as shown. On the arbor O, of the first toothed wheel, is wedged a pulley, of which the diameter is half that of the wheel. This pulley follows the motion, by means of a Vaucanson's chain (link chain), of a smaller pulley; the chain is fixed to a standard F, attached to the tube of the negative carbon-holder. According to the dimensions and arrangement of the first pulley, the negative carbon-holder is displaced higher, by a distance half that which the positive holder descends through. Thus is compensated the difference of consumption, which, for the negative carbon, is nearly half that of the positive carbon.

The descent of the positive carbon is regulated by means of a train of wheels, which terminates in a pinion, commanding, at the same time, a regulating fly and a small winged star, the importance of which will be seen later.

When the carbons require renewal, the massive bar of the positive carbon-holder is moved upwards: this operation causes the descent of the tube of the negative carbon-holder, under the

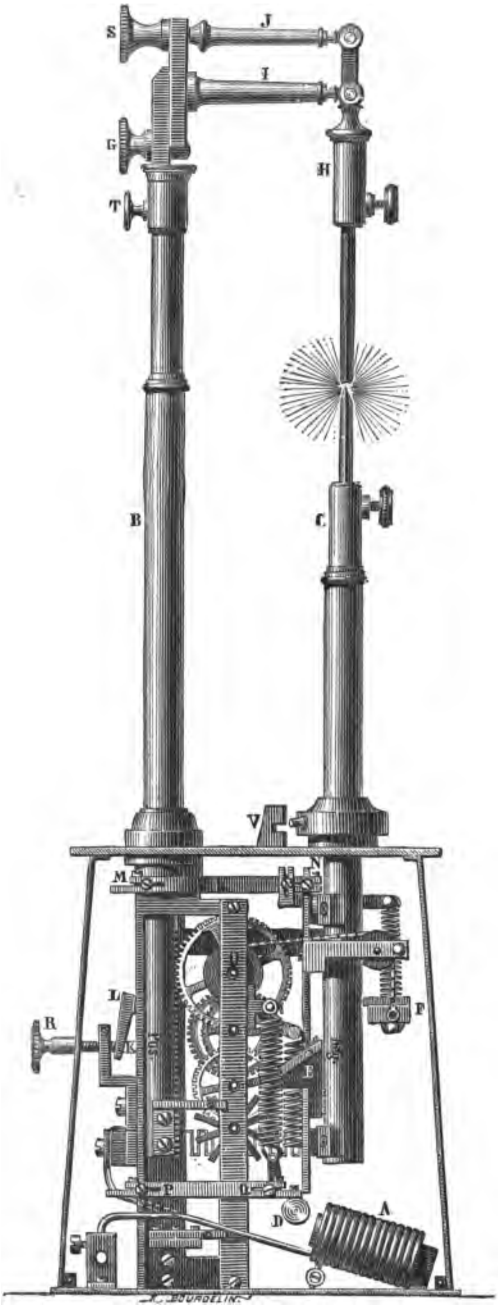

FIG. 9. SERRIN'S REGULATOR.

influence of its own weight, and does not determine any other movement of the train of wheels, because a pawl on the arbor of the second wheel keeps the system at rest.

2. *Establishing and Maintaining the proper Distance between the Points.*—This result is obtained by means of a double-jointed parallelogram M N P Q, the armature of soft iron D, and the electro-magnet A.

In the parallelogram, the vertical side M Q, next to the positive carbon-holder, is fixed; two sides, M N, P Q, can be separated in a horizontal direction; the third side, N P, is vertical, and the lower ends of these vertical movable sides are connected by a soft iron armature D.

The influence of the weight on the jointed parallelogram is counterbalanced by means of two spiral springs. One is attached at one end to the lower horizontal side, and at the other end to a fixed projecting piece; the other, connected at its base to the movable vertical side of the parallelogram, is fixed at the other end to the extremity of a bent lever L K, and can be adjusted by an exterior screw R.

The soft iron armature D, placed in relation to the electro-magnet A, will be attracted by the latter when the circuit is closed, and the intensity of the attraction will vary with the energy of the current.

The positive wire of the machine, clamped in a terminal, is put in communication with the body of the apparatus, and the electric current, passing from the upper (positive) carbon to the lower (negative) carbon, by the voltaic arc, leaves the lower carbon-holder, traversing the insulated conductor S, to the electro-magnet, and issues from the apparatus by an insulated terminal, to which the negative wire is attached.

The engraving shows that the tube of the negative carbon-holder is connected to the vertical movable side of the parallelogram. This is submitted to two forces which counterbalance: its weight, which tends to make it oscillate around the fixed stop, and the springs that tend to raise it. The action of the electro-magnet consists in overcoming at a given moment the power of the springs, and by attracting the soft iron armature to cause the parallelogram to descend. When the current in the electro-

magnet is weakened, the springs become in their turn the more powerful and raise the parallelogram.

It is easily perceived that in the first case the negative carbon descends, and that it rises in the second. In effect, the vertical movable side of the parallelogram carries a jockey E, the point of which can, as it descends, enter between the arms of a windmill wheel, detaining the movement of the train, and consequently of the racks. The lowering of the parallelogram engages the jockey, whilst it raises the detent, and consequently the rackwork is stopped in the first case, and left free to descend in the second case, causing the ascent of the negative carbon.

The button R acts by the lever L K on a spring which serves to regulate the apparatus in the following manner. When the light plays between the two carbon points, there is a distance (according to the intensity of the current), for which the lighting power is a maximum. To this distance corresponds a position of the parallelogram with relation to the action of the springs and of the electro-magnet. By varying by means of the lever the tension of the spring and the distance of the armature from the electro-magnet, there is quickly obtained the proper position of the parallelogram, and the distance of the points under the most favourable conditions.

It remains to review the operation in practice. Suppose that the carbons have been placed without the current again passing in the apparatus. The descending movement of the solid bar determines the ascending movement of the negative carbon until contact is established. From this movement the two bars descend together, but as the bar of the negative carbon-holder is connected to the vertical movable side of the parallelogram, it lowers the parallelogram, the jockey detains the windmill wheel, and all the mechanism is locked.

As soon as the current is sent into the apparatus, the electro-magnet becoming active, attracts the armature, sets the parallelogram oscillating, and consequently the lower carbon, the point of which is separated to a small distance from that of the upper carbon: the voltaic arc appears and connects the two points. Proportionally as the current becomes less energetic by consumption and the separation of the points, the electro-magnet

becomes less powerful, the action of the springs increases, the armature separates from the electro-magnet, and the parallelogram oscillating rises. Consequent upon this incessant movement of the parallelogram which by-and-bye descending with the armature, presently rises under the action of the springs, the windmill wheel is alternately engaged and disengaged; the rackwork consequently passes through by alternations of descent and stoppage, and the mechanism of approximation works in maintaining the carbons within the limits desired.

The advantage which the Serrin regulator presents to all others, is especially that its motor is powerful enough to ensure a certain constancy, by destroying small abnormal resistances which occur, without, in spite of that power, crushing the carbon points against each other or permitting them to glide parallel. As soon, as the lower bar descends a little, it immediately stops the windmill wheel, and thus withdraws the carbons in contact under the action of the weight of the upper bar. It suffices to properly tension the spring balancing the lower carbon-holder to obtain a movement having any property desired.

No other regulator possesses the property of having a motor that is both delicate and powerful in an equal degree, but this does not say that M. Serrin's apparatus has no defects; it has, with all things human, some imperfections, and, even though these imperfections are slight, it is useful to point them out.

All the movements produced by the electro-magnet on its armature are directly transmitted to the inferior carbon-holder, which incessantly oscillates when the carbons contain impurities. These oscillations increase or diminish alternately the length of the voltaic arc, and consequently its resistance. The current thus changes in intensity at every instant, and these changes react on the motor-machine and on the electro-magnet, which multiply the primary oscillation, and often give a very disagreeable instability to the light. Adding that the apparatus cannot be used horizontally nor with great inclination, and that its parts are somewhat too delicate for use in workshops, we have enumerated all its small inconveniences. In spite of this, we repeat that its normal service is satisfactory, and that it is

sufficient to take a little precaution to avoid serious mishaps. With carbons chemically pure, and a constant source of electricity, the amplitudes of the armature of the electro-magnet may be made nearly nil, and a light obtained as steady as that of an oil-lamp or well-regulated gas-burner.

Girouard's Regulator.

At the beginning of the year 1876, M. Girouard presented to the Institute an electric lamp of a special character. Opposed to the preceding combinations, the new lamp is divided into two distinct parts: (1) the lamp properly so called with clockwork movement for bringing together and separating the carbons; (2) the regulator in the form of a relay, which may be placed near the lamp, and which is worked by means of a small portable sulphate of mercury battery.

This system then has two apparatus, connected by two distinct circuits. One of these currents is very intense; it emanates from the machine and gives rise to the electric light after passing an electro-magnet fixed on the relay; the other, very feeble, only sets free the clockwork movements for the advancement and withdrawal of the carbons.

The lamp contains two clockwork movements commanded by a single barrel. These movements are governed by a detent depending upon a special electro-magnetic system, which corresponds electrically with two small contacts on the relay.

This system may be used in all positions; it is likely therefore to be applied to theatrical representations, naval manœuvres, physical experiments, &c. In ordinary industry, it does not offer sufficient advantages to compensate the complication occasioned by the use of the battery and of secondary relay mechanism.

Carré's Regulator.

M. Carré patented in 1875 an electric regulator with clockwork movement, having, like that of M. Serrin, the positive carbon for motor. Instead of an electro-magnet, M. Carré employs a double solenoid of particular shape. The armature

of this solenoid is S-shaped: it oscillates by its centre around a fixed point, and enters at each of its extremities (whilst the current passes) into a curved bobbin.

The winding of the wire on the bobbin of the solenoid is so made, that the actions of the bobbins add to and follow that of the armature in the same direction.

When the current does not pass, the armature is retrograded by the effect of two opposing springs, a pawl disengages the escapement of the mechanism and the carbons come into contact. As soon as the current traverses the apparatus, the armature is sucked into the solenoid and produces separation of the carbons.

The attraction of the armature increases regularly, in direct proportion to its entrance into the bobbins, provided its path does not exceed certain limits.

We have tried a regulator on this system, and we have been satisfied with the results, only the apparatus which was used in our trials (from the workshops of M. Bréguet) was designed with a view more to laboratory experiments than to industrial lighting.

Some changes in the carbon-holders, a more perfect study of the exterior parts and of the movement itself, without change of principle, would render this apparatus practicable and allow of its rivalry with that of M. Serrin. It is already a good physical instrument, it remains to fit it for the workshop.

Electric Lighting without Regulators.

M. Jablochkoff, an officer in the Russian army, patented in March, 1876, for the production of the voltaic arc, a new arrangement of electrodes which completely suppresses the regulator.

This invention was presented to the Academy of Sciences by M. Denayrouze, 30th October, 1876.

The carbons instead of being opposed are placed side by side, and are separated by an insulating fusible substance, such as porcelain for example. When the current begins to pass, the voltaic arc plays between the ends of the carbons. The layer of

insulating matter melts, volatilises, and the double rod of carbon slowly consumes, exactly, says M. Denayrouze, as the wax of a candle progressively exposes its wick.

The Jablochkoff candle has special properties. The heat of combustion of the carbons, lost in the atmosphere with regulators, is utilised with the candle for the fusion and volatilisation of the insulating mixture. The composition of this may be infinitely varied, because the majority of earthy substances may be employed. Matter reputed the most infusible volatilises when introduced into the voltaic arc.

In September, 1876, M. Jablochkoff, in an addition to his patent, indicates the possibility of obtaining several colorations by introducing into the insulator various metallic oxides.

In October, a second addition indicates the elements of a system of lighting comprising a number of luminous points, and the means of lighting and burning independently of one another, by the use of a secondary battery, the different foci of this system.

Towards the end of the same month, M. Jablochkoff stated, in a further addition, that instead of separating the carbons by compact bodies, it is preferable to employ powders. "The carbons are surrounded by a cartridge of asbestos, and the carbons are separated from one another by the same powdered. The voltaic arc burns all."

In November, the inventor points out a fresh improvement, which consists in suppressing carbon rods, and replacing them by tubes filled with a substance analogous to the insulating substance.

Finally, on the 20th November, M. Jablochkoff took out a new patent for a system of obtaining with a circuit from a single source, as many luminous foci as may be desired. This system is based on the use of induction coils enclosing other bobbins induced by the first, and put into connection with the two poles of the luminous focus to be produced.

It is to be hoped that the interesting labours of M. Jablochkoff may have practical result, and that they may notably increase the domain of electric lighting.

CHAPTER III.

ELECTRIC CARBONS.

Wood Carbon Rods — Retort Carbon — Its Inconveniences — Staite and Edwards' Carbons—Le Molt's Carbons—Lacassagne and Thiers' Carbons—Curmer's Carbons—Jacquelain's Carbons—Peyret's Carbons—Archereau's Carbons—Carré's Experiments—His Processes of Manufacture—Gaudoin's Experiments — His Processes of Manufacture — Comparative Trials of several kinds of Carbons.

In his experiments on the voltaic arc, Davy made use of rods of wood carbon extinguished in water or mercury. These rods burnt with great brilliancy, and in a very regular manner, but they wore away so rapidly that their use was obliged to be reserved for laboratory experiments. In replacing the wood carbon by the deposits collected from the walls of gas retorts, Foucault really opened up to the voltaic arc the epoch of useful applications. Retort carbon is, in fact, much more dense, and resists for a long time the destructive action of the voltaic focus.

But, as M. Le Roux has observed with reason, the last word has not been said upon this question, and retort carbon will still offer grave inconveniences: its density is far from uniform, it sometimes splits, frequently works irregularly, and produces considerable variations in brilliancy. These variations chiefly depend upon the presence of foreign matters, such as alkaline or earthy salts, and also notable quantities of silica. These matters are much less refractory than the carbon; they pass into vapour, and form for a great part the flame which envelopes the arc. This flame is more conducting than the voltaic arc proper; moreover, as it has a much greater section it is less heated, and besides, as it is a gaseous body, its power of radiation is less than that of the particles of carbon which constitute the arc.

Let us hasten to say that, by suitably choosing the two rods which should furnish a regulator, retort carbon gives satisfactory results in most of its applications.

When the voltaic arc is enclosed in a globe of frosted glass, the scintillations, intermittences, and variations in the intensity of the focus are much less felt; the shadows are much less marked, the light is softer, more homogeneous, more agreeable. But the globe causes a very considerable loss of light, and whenever the small irregularities, due to the imperfection of the carbon, are supportable, the carbons should be burned without a globe. Moreover, one gets readily accustomed to the electric light; and workmen now, instead of complaining, seek factories lighted in this manner.

Several inventors have endeavoured to substitute for carbons cut directly from the deposits on the walls of retorts similar agglomerates, but purer; others have merely purified retort carbons. Some have obtained products very remarkable in respect of luminosity, but practically inapplicable on account of their extreme cost.

Among the processes proposed for the improvement of electric carbons, we will cite those of Messrs. Staite and Edwards, Le Molt, Lacassagne and Thiers, Curmer, Jacquelain, Peyret, Archereau, Carré and Gaudoin.

Staite and Edwards' Carbon.

In 1846, Messrs. Staite and Edwards patented a process for the manufacture of carbons for the electric light, which had for its base a mixture of pulverised coke and sugar.

The coke is first reduced to a nearly impalpable powder, and a small quantity of syrup added, the mixture being pugged, moulded, and strongly compressed. Then the carbon is subjected to a first heating, and plunged into a very concentrated solution of sugar, and again subjected to a white heat.

Le Molt's Carbon.

M. Le Molt, in 1849, patented a composition for electric carbons, consisting of 2 parts of retort carbon, 2 parts of wood charcoal or of coke, and 1 part of tar. The substances were in the first place pulverised, pounded, mixed, and by much tritura-

tion brought to the state of a stiff paste; then, by the aid of powerful mechanical means, subjected to great compression.

The moulded pieces were covered with a coating of syrup, and placed beside each other in a vessel of retort carbon. They were then subjected to a high temperature for a period of from twenty to thirty hours, and purified, if necessary, by immersion in acids.

Lacassagne and Thiers' Carbon.

In 1875, Messrs. Lacassagne and Thiers gave attention to the purification of retort carbons. They fused a certain quantity of caustic potash or soda. When this bath was at a red heat they digested in it, for about a quarter of an hour, the carbon rods which had been previously cut from the walls of retorts.

This operation was intended to change into a soluble silicate of potash or soda the silica contained in the carbons which is so pernicious to the constancy of the light. The carbon rods were then washed in boiling water, and subjected for several hours (in a red-hot tube of porcelain or fire-clay) to the action of a current of chlorine, which had the effect of converting the different earthy matters that the alkali had not attacked into volatile chlorides, as of silica, calcium, potassium, iron, &c. Thus cleansed, these carbons gave a somewhat more regular light.

Curmer's Carbon.

Curmer's process consists principally in the calcination of lamp-black, benzine, and oil of turpentine, the whole mixed and moulded in the form of cylinders; the decomposition of these substances leaves a porous carbon, which is soaked with resins or saccharine matters and again calcined. By repeating these operations, M. Curmer succeeded in producing carbons of small density or conducting power certainly, but extremely regular, and free from all impurities.

Jacquelain's Carbon.

M. Jacquelain, late chemist at l'École Centrale, has endeavoured to imitate the circumstances which, during the manufacture of gas, give birth to retort carbon. These circumstances are the

coming into contact with the white-hot walls of the retort of very dense hydrocarburetted matters, of which part is volatilised and the rest decomposed, leaving as residue a layer of carbon. In the retorts used in the manufacture of gas, these hydrocarburetted matters carry away with them a great number of the impurities that the coal contains. By taking the tars resulting from true distillation, cleared consequently of all the non-volatile impurities, and realising, in special apparatus, these conditions of decomposition in contact with highly heated walls, retort carbons ought to be reproduced possessing perfect purity. It is this that M. Jacquelain has done in operating with a tube of refractory earth of 0·15 mètre diameter, in an improvised furnace; and he has obtained some plates which, cut into rods with a saw, have given a light perfectly steady, whiter, and of about 25 per cent. greater intensity, with an equal electric current, than that given by the ordinary carbons.

The experiments made with these carbons, by the Paris Administration of Lighthouses, have been so conclusive that we had, about the commencement of 1876, the idea of putting the process in practice. But M. Jacquelain, being consulted, explained to us that it was impossible to calculate: 1st, the expenditure necessary for the establishment of a continuous manufacture; 2nd, the approximate nett cost price of the carbons obtained. As another process by M. Gaudoin has commenced to give good results, we have not continued our idea. We have long ago learnt what is the cost of converting a very exact laboratory process into an industrial operation, and we do not wish to launch into an affair of this nature without some figures being given.

The carbon of M. Jacquelain, once formed, has always the inconvenience of requiring a considerable amount of manual labour before use can be made of it (because the material is so hard, that it can with difficulty be cut by the saw), and of producing relatively considerable waste.

Peyret's Carbon.

M. Peyret, a physicist of Lourdes, has prepared carbons by soaking pieces of elder-tree pith or any other porous body with

liquefied sugar, and afterwards decomposing the sugar by heat. By repeating the operation a sufficient number of times, he obtained very dense carbons, which he then submitted to a current of sulphide of carbon.

We have had in our hands only very small fragments of these carbons, and it has been impossible for us to give an estimate of their worth; their high price is in every case a very serious obstacle to the development of an industrial manufacture.

Archereau's Carbon.

M. Archereau, whose name frequently comes under the pen in questions relating to agglomerates of carbon or to electricity, has presented to the Academy of Sciences some new rods for electric regulators, composed of carbon mixed with magnesia, agglomerated and pressed; the magnesia has, according to the author, the advantage of making the light more steady and of augmenting its lighting power.

We have tried several samples of these carbons, some were of good quality, others inferior to retort carbons. Several carbons furnished a light of 150 burners, with a total consumption per hour of 0·03 mètre. It is a manufacture that is capable of giving good results, but needs very careful revision.

Carré's Carbon.

M. Carré has made a great number of experiments for the electric light upon retort carbons impregnated with different salts, and has combined a new product for the same usage. Some details of his labours are necessary to make their importance and merit understood.

By impregnating porous carbons, and by a prolonged ebullition in concentrated solutions, M. Carré proves:

1st. That potash and soda at least double the length of the voltaic arc, render it more silent, combine themselves with the silica and eliminate it from the carbons by making it flow to 6 or 7 millimètres from the points in a state of vitreous globules, limpid, and often colourless; that these substances augment the light in the proportion of 1·25 to 1;

2nd. That lime, magnesia, and strontia augment the light in the proportion of 1·40 to 1, by the colouring in different ways;

3rd. That iron and antimony carry the augmentation to 1·60 or 1·70;

4th. That boracic acid augments the duration of the carbons by enveloping them with a vitreous layer which isolates the oxygen from them, but without augmenting the light;

5th. That upon the whole the impregnation of pure and regularly porous carbons, with the solutions of different substances, is a convenient and economical means of producing their spectra, but that the mixing of the simple substances with the carbon compound is preferable.

For the manufacture of carbons, M. Carré recommends a composition of powdered coke, calcined lamp-black, and a special syrup formed of 30 parts of cane sugar and 12 parts of gum.

The following formula is recommended in the patent of the 15th January, 1876:

Coke, very pure, in fine, nearly impalpable, powder..	15 parts.
Calcined lamp-black	5 „
Special syrup	7 to 8 „

The whole is strongly triturated, and has added to it from 1 to 3 parts of water, to compensate for the loss by evaporation, according to the degree of toughness to be given to the paste. The coke ought to be made with the best coals, pulverised and purified by washings. (The coal powder may be likewise purified by washings by decantation and maceration with heat in acid baths.) The coke dust of gas retorts is generally pure enough.

The paste is now pressed and passed through a draw-plate, then the carbons are placed in tiers in crucibles, and are subjected during a given time to a high temperature.

The cooking comprehends a series of operations.

For the first, the carbons are placed horizontally in the crucible resting upon a bed of coke dust, every layer is separated by a cover of paper to avoid any adherence. Between the last layer and the cover is put one centimètre of coke-sand, and one centimètre of silicious sand upon the joint of the cover.

After the first operation, which ought to last from four to five hours and attain a cherry-red heat, the carbons should remain

two or three hours in a very concentrated and boiling syrup of cane sugar or caramel, with two or three intervals of considerable cooling, in order that the atmospheric pressure may force the syrup into all the pores. The carbons are then left to drain by opening a cock placed at the bottom of the vessel, after which they are agitated for some instants in boiling water to dissolve the sugar remaining on the surface.

After desiccation the carbons are submitted to a second cooking to the degree required; they are then stood up in the crucible by filling up their interstices with sand.

They are thus manipulated from stage to stage until they have acquired the density and solidity requisite, and the manipulation is facilitated by the use of an oven having as many stages as there are cookings required.

The carbons are dried slowly. Their desiccation is completed in a stove, the temperature of which attains gradually 80 degrees in twelve or fifteen hours. To prevent their becoming deformed in drying, the rods are placed on pieces of sheet iron having a V-form.

The Carré carbons are more tenacious and are harder than those of retort carbon. They are remarkably accurate and regular. Rods of 0·01 mètre diameter and of 0·5 mètre length can be employed without fear of rupture. Their cylindrical form and their homogeneity make the cones maintain as perfect shape as if they were turned. They are also better conductors than retort carbons. The only inconvenience that we have remarked in their employment is a rapid disaggregation, the production of small sparks, and irregularity of the luminous brilliancy.

Gaudoin's Carbons.

M. Gaudoin also has made numerous experiments upon carbons containing foreign substances.

The following bodies have been introduced into the carbons:

1st, phosphate of lime from bones; 2nd, chloride of calcium; 3rd, borate of lime; 4th, silicate of lime; 5th, pure precipitated silica; 6th, magnesia; 7th, borate of magnesia; 8th, phosphate of magnesia; 9th, alumina; 10th, silicate of alumina.

The proportions were calculated in such a manner as to obtain five per cent. of oxide after the cooking of the carbons. These were submitted to the action of an electric current always of the same direction, furnished by a Gramme machine powerful enough to maintain a voltaic arc of 10 to 15 millimètres in length.

The negative carbon being placed at the bottom, M. Gaudoin has observed the following results:

1st. The complete decomposition of the phosphate of lime under triple influence of electrolytic action, calorific action, and reducing action of the carbon. The reduced calcium goes to the negative carbon and burns in contact with the air with a reddish flame. The lime and phosphoric acid are diffused into the air, producing abundant fumes. The light, measured by a photometer, is double that which is produced by carbons of the same section cut from the residue of gas retorts.

2nd. Chloride of calcium, borate and silicate of lime are also decomposed, but the boracic and silicic acids appear to escape, by volatilisation, from the electric action. These bodies give less light than the phosphate of lime.

3rd. Silica introduced into the less conducting carbons, melts and volatilises without being decomposed.

4th. Magnesia, borate and phosphate of magnesia are decomposed, the magnesium in vapour goes to the negative carbon and burns, in contact with the air, with a white flame. The magnesia, boracic and phosphoric acids diffuse into the air in a state of vapour. The increase of light is less considerable than with the lime salts.

5th. Alumina and silicate of alumina are decomposed only with a very strong current and a very considerable voltaic arc, but under these circumstances the decomposition of the alumina is well manifested, and the alumina, in vapour, is seen to go off from the negative pole like a jet of gas, and burn with a blue flame of little lighting power.

The flame and vapour which constantly accompany these electro-chemical lights having appeared to him a great obstacle to their utilisation for illumination, M. Gaudoin has not pushed these experiments further. He has preferred to follow up his studies upon the agglomeration of carbon.

The products manufactured by M. Gaudoin being superior to all others, we will expatiate a little upon this mode of manufacture.

The patent is dated 12th July, 1876.

As we have said above, the carbons intended for the production of the voltaic arc ought to be chemically pure. Thus, the dust of retort carbon, though containing only a small proportion of foreign matters, is not sufficiently pure for this use, and its employment presents some inconveniences. The washings in acids or alkalies to which the carbonaceous matters may be submitted, with the aim of extracting the impurities they contain, are costly and insufficient. Lamp-black is pure enough, but its price is high and its management difficult. Owing to this, M. Gaudoin had to seek elsewhere a better source of carbon, and he has found a solution of the problem in decomposing, by heat in closed vessels, the dried pitches, fats or liquids, the tars, resins, bitumens, natural or artificial essences or oils, organic matters capable of leaving behind carbon sufficiently pure after their decomposition by heat.

The apparatus employed to effect this decomposition are closed retorts or crucibles of plumbago. These crucibles are placed in a furnace capable of being heated to a bright red. The lower parts of the crucibles are furnished with two tubes, serving, one for the disengagement of gas and volatile matters, the other for the introduction of the primary material. The volatile products of decomposition may be conducted under the hearth of the furnace and there burnt for heating the crucibles, but it is more advantageous to conduct them into a condensing chamber or into a copper still, and to recover, after condensation, the tars, oils, essences, and hydrocarbons that are produced in this operation.

M. Gaudoin utilises these different sub-products also in the manufacture of his carbons; he takes great care to avoid for the worms and receivers the use of iron, zinc, or any substances susceptible of being attacked by these tars, because the whole value rests in purity.

Whatever may be the primary material employed for the manufacture of this carbon, the decomposition by heat should be

able to be conducted either slowly or quickly according to the nature of the sub-products that it is proposed to obtain. For operating slowly it suffices to two-thirds fill the retort and to heat gradually up to a clear red, avoiding as much as possible the boiling over of the substances. For operating quickly, the empty retort is heated to a deep red, and the primary material thrown into the bottom in small quantities, in a thin stream if it is liquid, and in small fragments if it is solid. The slow distillation gives most tars and heavy oils and little gas. The quick decomposition gives more light oils and gas.

When the primary material has been properly chosen, there remains in the retort, carbon more or less compact. It is pulverised as finely as possible, and agglomerated alone or with a certain quantity of lamp-black by means of the carbides of hydrogen obtained as secondary products.

Thus prepared, those carbides are completely free from iron, and are much preferable to those found in commerce, not only in the agglomeration of the carbons, but also in the impregnation or soaking of the manufactured objects. (The last operation, by filling up the pores, introduces oxide of iron when effected with commercial products.)

The objects made in agglomerated carbon are, for one variety of carbon, as much more combustible as they are porous, and as much more porous as they are moulded with less pressure. The inventor himself uses, for his manufacture, steel moulds capable of resisting the highest pressure of a strong hydraulic press.

Although the draw-plate or moulding apparatus, used long since in the manufacture of ordinary graphite carbons, may be used, without any modification, for the manufacture of carbons for the electric light, M. Gaudoin has added to this apparatus certain important improvements. Thus instead of causing the carbons to issue from top to bottom, vertically, he places the orifice or orifices of the mould upon the side, and in such a manner that the issuing carbons form with the horizon a descending angle of 20 to 70 degrees. The carbon is guided for the whole length by tubes or gutters. This arrangement allows of emptying the whole of the matter contained in the mould without interrupting the work, and as the carbon is constantly

supported it does not break under its own weight, which frequently happens when issuing vertically.

We have made, at different times, numerous trials with all kinds of carbons, and those of M. Gaudoin's manufacture gave the best results. It has necessitated much time and considerable expense to remove this manufacture from the merely scientific domain to that of the practical, but success has crowned the efforts of the inventor. (Table A.)

The light produced with the retort carbons was equal to 103 burners, and that produced by the artificial carbons varied between 120 and 180 burners for the Archereau and Carré carbons, and between 200 and 210 for the Gaudoin carbons. The mean of 150 burners may be applied, without appreciable error, to the Archereau and Carré carbons, and that of 205 to the Gaudoin carbons.

Brought to a uniform section of 0·0001 square mètre, the consumption of the carbons was respectively:

For retort carbons	51	millimètres.
Archereau	66	„
Gaudoin	73	„
Carré	77	„

In proportion to the light produced this consumption was:

For the Gaudoin carbons	35	millimètres per	100 burners.
„ Archereau „	44	„	„
„ Carré „	51	„	„
„ retort „	49	„	„

These experiments were made with a Gramme machine constructed by M. Bréguet and a Carré lamp by the same maker. The carbons were taken at hazard from a lot of several mètres for each series.

At the request of one of the inventors we made some fresh experiments, with the co-operation of Messrs. Gramme and Lemonnier, with a more powerful Gramme machine and a Serrin lamp.

The following Table (B) contains the mean of three series of experiments made with the greatest precision. The electric lamp was placed, quite vertically, at the same level as the oil-

(TABLE A.)

TABLE OF EXPERIMENTS MADE WITH SEVERAL ELECTRIC CARBONS, 6th November, 1876.

Name of Carbon.	Dimensions.	Speed of Machine.	Consumption				Regularity.	Observations.
			Of Negative Carbon.	Of Positive Carbon.	Total per Hour.	Mean of Two Experiments.		
			m.m.	m.m.	m.m.	m.m.		
Retort	9 m.m. square ..	800	19	36	55	63	Irregular	Scintillating, eclipsed for a short time, a slight disaggregation.
,,	9 m.m. square ..	920	23	48	71		Sufficiently regular	
Archereau ..	10 m.m. diam. ..	800	20	60	80	85	Sufficiently regular	A slight disaggregation, a few sparks. Cinders of Oxide of Iron in rather large quantity. White light. Cones good.
,,	10 m.m. diam. ..	920	30	60	90		Sufficiently regular	
Carré	10·4 m.m. diam.	800	18	60	78	92	Irregular	A slight disaggregation, a few sparks; more Cinders than the preceding, reddened for a greater length.
,,	10·4 m.m. diam.	920	26	80	106		Regular enough	
Gaudoin ..	11·3 m.m. diam.	800	20	38	58	73	Very regular ..	Neither disaggregation nor sparks; less Cinders than the Carré and Archereau Carbons.
	11·3 m.m. diam.	920	38	50	88		Very regular	

lamp and photometer. Every precaution was taken that there should not be any sensible error in the measurements of the luminous intensity.

(TABLE B.)

RESULTS OF EXPERIMENTS UPON SEVERAL CARBONS, 4th April, 1877.

Name of Carbon.	Form and Dimensions.	Section in Square Millimètres.	Total Consumption per Hour in Millimètres.	Mean Light in Carcel Burners.	Length of the Arc in Millimètres.	Revolutions per Minute of the Machine.	Regularity.	Observations.
Retort Carbon, good quality	Square, 9 m.m. in the side	81	60	120	2·5	820	Passable	Splinters numerous. Separation of a small piece. Scintillation. Carbons were shaped very irregularly.
Archereau's Carbons, new specimen	Round, 10 m.m. diam.	78	68	173	3	820	Null ..	Disaggregation. Sparks. Light very variable in intensity at periods. Shaping into small facets.
Carré's Carbons, new specimen	Round, 9 m.m. diam.	64	69	175	3	820	Middling	Small Sparks. Light running round. Very variable in intensity. Good shaping of the Carbons.
Gaudoin's, Type No. 1.	Round, 11·2 m.m. diam.	98	80	203	3	820	Good ..	Neither Sparks nor Splinters. Light a little red, but pretty constant.
Gaudoin's (Agglomeration of wood Carbon)	Round	—	78	240	3	820	Sufficiently good	Light very white. Less steady than with Gaudoin's Carbons, No. 1. No Sparks. Small variations.

Brought to a uniform section of 0·0001 square mètre, the consumption of the carbons was respectively in these new experiments:

For the	Carré carbons	44 millimètres.
"	Retort	49 "
"	Archereau	53 "
"	Gaudoin (wood carbon)	61 "
"	Gaudoin, No. 1	78 "

In proportion to the light produced, this consumption was:

For the	Gaudoin (wood carbon)	32 millimètres per 100 burners.
"	Archereau	39 " "
"	Carré	40 " "
"	Gaudoin, No. 1	40 " "
"	Retort	50 " "

The light given by the Gaudoin carbons was a little less regular than that observed 6th November, 1876. That given by the Carré carbons varied in less than a minute from 100 to 250 burners; the arc rotated positively round the points, the same as if alternating currents were being used. The Archereau carbons appeared to us less effective than at the first trial; they were consumed slowly, but they produced a light so variable that it was difficult to take photometric measurements. Only the retort carbons maintained their duration, luminous intensity, and, unfortunately, their irregularity.

We shall describe, in terminating this chapter, the improvements that M. Gaudoin has made in his process, and patented, 7th April, 1877.

Instead of carbonising wood, reducing it to powder, and then submitting it to mixture, the inventor takes dried wood, properly chosen, to which he gives the definite form of the carbon, then he converts it into hard carbon, and finally soaks it, as in the manufacture we have described.

The distillation of the wood is effected slowly, in such manner as to drive out the volatile substances, and the final desiccation is made in a reducing atmosphere, at a very high temperature. A previous washing, in acids or alkalies, removes from the wood any impurities that it possessed.

M. Gaudoin points out also the means of filling up the pores of the wood, by heating to redness, and submitting it to the action of chloride of carbon and different carbides of hydrogen. He hopes thus to produce electric carbons of small consumption, and giving an absolutely steady light.

CHAPTER IV.

MAGNETO-ELECTRIC MACHINES.

Definition—Transformation of Work into Electricity—Influence of a Current upon a Magnetic Needle—Œrstedt's Experiment—Mutual Action of Two Currents—Ampère's Discovery—Action of a Current on Soft Iron—Arago's Discovery—Action of a Magnet on a Metallic Helix—Faraday's Discovery and Experiments—Induced Electricity—Pixii's Machine: Commutator—Clarke's Machine—Niaudet's Machine—Nollet's, or the "Alliance" Machine—Holmes' Machine—Wilde's Machine—Improvements by Wheatstone and Siemens—Residual Magnetism—Ladd's Machine—Lontin's Machine.

THE term *magneto-electric machine* is given to a collection of parts or mechanism intended to create and gather together induced electric currents.

The operation of a magneto-electric machine necessitates the intervention of some motor, animate or inanimate, and, for the same kind of apparatus, the motive force employed is as much greater as the electricity produced is greater. The machines may be defined by saying that their object is to transform work into electricity.

When magnets are replaced by electro-magnets, these machines are often defined under the term *dynamo-electric*, to avoid confusion with those constructed with ordinary magnets, or with Jamin magnets.

We preserve the first name because magnetism is the source of the current, the same with magnets as with electro-magnets, and because it is necessary to distinguish induction machines with glass plates, which also transform work into electricity.

If it were wished to give a more complete designation, we would term as *dynamo-electric machines* all those necessitating a motor, and *dynamo-magneto-electric* all those requiring both a motor and a magnet. For the sake of simplicity, we do not add the word *dynamo*, and we shall designate each machine by the name of its inventor. Some scientific details are necessary

to explain the principle and the mode of working of magneto-electric machines.

In the month of July, 1820, Œrstedt, a Danish physicist, remarked that a magnetised needle is deflected from its direction when it is placed near a closed electric circuit. The same phenomenon occurring when the current is replaced by a magnet, it became evident to Œrstedt, as to all contemporary physicists, that a complete analogy exists between electricity and magnetism.

From that first observation really dates one of the most beautiful of the conquests of the human mind in the domain of natural philosophy. In the scientific world, even before 1820, the intimate relation existing between the electric current and a magnet is often spoken of: this fact even served as a base for several electrical theories, but no one had rendered it palpable, and it is Œrstedt's experiment alone that opened to science the luminous path which scientific men have followed with so much success.

On the 11th of September, 1820, M. de la Rive repeated Œrstedt's experiment at Paris, before the Academy of Sciences; eight days after, the 20th September, Ampère made known the mutual action of two currents and of magnets on currents; the 25th September, Arago discovered that an electric current can impart magnetic properties to a bar of iron or steel. Never did discoveries on such a subject succeed with more rapidity, or more quickly receive theoretical explanation, and give rise to more admirable applications.

It is the English physicist, Faraday, who, in 1830, had the honour of completing the labours of Œrstedt, Ampère, and Arago, by demonstrating that a magnet could create an electric current.

Faraday found, by numerous experiments, that, if a bar-magnet is introduced into a bobbin or coil of insulated wire, it determines an electric current therein. He also found that when a circuit is traversed by an electric current of a certain direction, and there is approached to it another circuit not traversed by a current, during the time of the approximating movement, there is created an electric current in the second circuit, which current is in inverse direction to the first.

The currents developed by the influence of a magnet, or of an electrified circuit, are termed *induction currents*, or *induced currents*. The magnetised bar, or the first current, having given rise to induced currents, is termed the *inductor* or *inducing current*.

Fig. 10 shows, as Faraday made it, the experiment of inducing currents by the aid of magnets. He took a bobbin, having a single wire of 200 or 300 mètres in length, open in the interior, and placed on a baseboard. Beneath the baseboard, the two ends of the wire are carried to two terminals, from which two copper wires establish communication with a galvanometer.

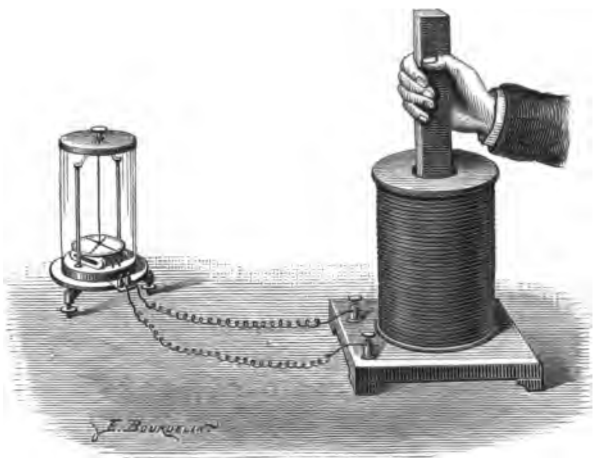

FIG. 10.

By suddenly introducing a magnet into this coil, the illustrious physicist observed the following phenomenon:

(1) At the instant when the bar enters the bobbin, the galvanometer indicates the existence of a current of a certain direction; (2) when the movement is arrested, the needle returns to zero; (3) when the bar is withdrawn, the galvanometer indicates a current of inverse direction to the first.

Fig. 11 represents the experiment of an inductor current and an inert spiral. A hollow coil, furnished with a long and thin wire, is put into connection with a galvanometer, and a second

bobbin, with a thick and short wire, is connected to a battery, and consequently traversed by a voltaic current. If the upper

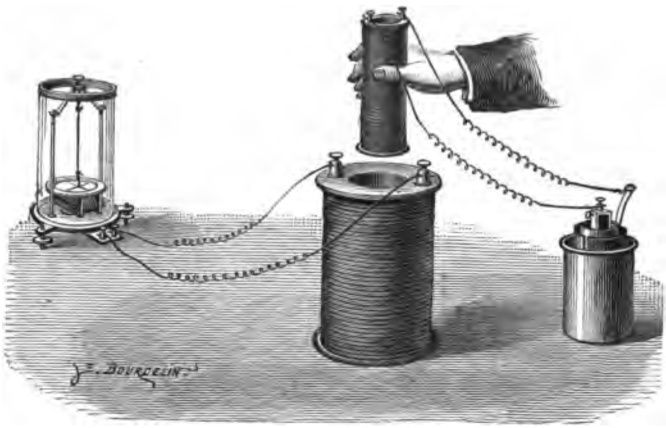

FIG. 11.

bobbin is plunged into the other, there is instantly produced in the lower bobbin a current inverse to that of the inducing coil. This current ceases whilst the smaller bobbin remains within the larger, but there arises a direct current upon the instant when the inducing bobbin is rapidly withdrawn.

Faraday also made a very beautiful experiment to prove that there exist induced currents in a metallic circle revolved rapidly before the poles of a magnet, and his extremely simple apparatus may be considered as the first magneto-electric machine ever constructed.

In 1832, Pixii, a manufacturer of physical instruments at Paris, combined a very ingenious machine to realise practically Faraday's experiments, and since this time a large number of solutions of the same problem have been proposed.

Among the more important labours following this order of ideas, are those of Saxton, Clarke, Nollet, Siemens, Wheatstone, Ruhmkorff, Wilde, Pacinotti, Holmes, Ladd, Bréguet, Gramme, Niaudet, &c. A fine collection of magneto-electric machines was exhibited at South Kensington Museum in 1876, containing nearly all the arrangements invented since forty years.

We should deviate too far from the main subject of this work were we to give a detailed description of all the machines that have been practically realised, even if we confined ourselves to those that have been successful; those of our readers who wish to have complete information on this interesting question should consult the collection of French and English patents, and the treatises of Jamin, Waguin, du Moncel, &c.

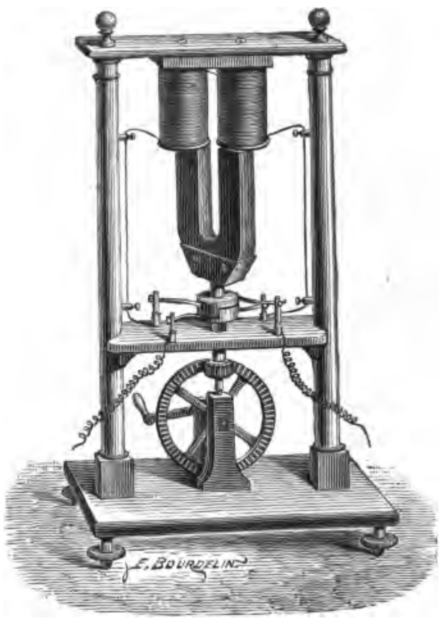

FIG. 12. PIXII'S MACHINE.

We intend simply to give some details on the experimental machines of Pixii, Clarke, and Niaudet, and on the electric light machines of Nollet, Wilde, Ladd, and Holmes.

Pixii's machine (Fig. 12) consists of an electro-magnet, a magnet, a wooden base and frame, mechanism for transmitting motion, and a small apparatus for directing the currents.

The electro-magnet is attached to the upper part of a small gallows, and the magnet is arranged to turn rapidly before the electro-magnet, pole to pole. A handle and a pair of bevel

wheels suffice to work the magnet. The arrangement of the apparatus is very primitive, but it is sufficiently satisfactory when regard is had to the date of its construction.

When movement is imparted to the magnet its poles are made to pass successively before the poles of the electro-magnet. There is produced at each half-revolution in the wire of the coils a current which is propagated in the conducting wires parallel to the vertical standards. This current, which is proportionally more intense the more nearly the poles of the magnet pass those of the electro-magnet, is alternately direct and inverse, and for many applications it must be redirected. This is effected by means of a *commutator* placed on the axis of rotation above the table.

FIG. 13. COMMUTATOR.

The commutator being one of the most important parts of induction machines with alternating currents, it is useful to form some idea of its use and of the principle on which it is based.

Let A and B (Fig. 13) be the two halves of a cylinder, completely insulated one from another by a badly conducting substance F G, and each connected with one of the poles of a voltaic battery. So long as the cylinder remains at rest, the friction springs C and D and the conductor H J attached thereto, are affected by a direct current; but when the cylinder is made to rotate on its axis, the current collected by the friction springs will change its direction. This needs no further demonstration.

If, however, the cylinder A B is connected on to the axle of an induction machine, combining the arrangement so that the axle may turn with or without the cylinder, and if the half-cylinder A is connected to one coil of the electro-magnet and the half-cylinder B to the other, there happens the exact contrary of that which occurred with a voltaic battery. It is evident that when the cylinder A B is fixed and the machine is in motion, at every half-revolution the conductors H J will be

affected by currents alternately direct and inverse, and that when the cylinder A B participates in the motion of the machine the currents collected will be always in the same direction: because the apparatus is so arranged that the current in the electro-magnet changes its direction at the same instant that the friction springs C D change on the half-cylinders.

Such is, in substance, the principle of all commutators; their form and combination in detail may be infinitely varied, but the principle on which they are based is always the same: to present the inverse poles of a circuit to the friction-pieces at each inversion of the current in the machine. The best known commutators are those of Ampère, Clarke, Ruhmkorff, Bertin, &c.

In all machines intended for chemical decomposition it is absolutely necessary to redirect the currents. For the production of the electric light this is not requisite.

That part of the commutator where the friction-pieces quit one of the conductors in order to pass to the other, is ordinarily the seat of multiple sparks, which are very intense and rapidly destroy this portion of the apparatus, and are often an insurmountable cause of non-success in machines well designed, commutator apart, for industrial work.

Practice having proved that it was useless to make the electro-magnet so massive as in Pixii's, whilst there was advantage in increasing the power of the permanent magnet, Saxton combined a machine with horizontal electro-magnet, revolving before the poles, placed end to end, of a magnet, also horizontal, and Clarke realised the same idea by setting the magnet vertically and the electro-magnet horizontally, and not end to end. Although this improvement was not primordial, and although the merits of Pixii and Saxton are greater and more generally appreciated by scientific men than those of Clarke, the name of the last has prevailed to characterise all classes of machines with alternating currents.

Clarke's apparatus (Fig. 14) consists of a bundle of magnets, curved in horse-shoe shape, and fixed on a vertical base. Before this bundle are two bobbins, revolved by means of a bevel wheel acting on a small crown wheel mounted on the axle of the

bobbins. The coils are wound on two cylinders of soft iron, connected together by a piece of the same metal. At each half-revolution the poles of the electro-magnet pass very near to the poles of the permanent magnet, and a commutator placed at the

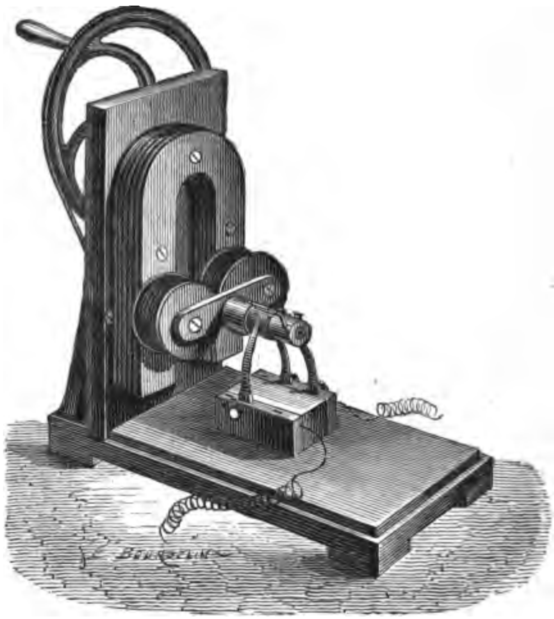

FIG. 14. CLARKE'S MACHINE.

extremity of the arbor redirects the currents. These currents pass by the friction-springs to the conductors, and may be led to a voltameter or other experimental apparatus.

Recently, M. Alfred Niaudet has combined a multiple Clarke machine, possessing the special advantage that a commutator for the production of currents in one direction is included in the same apparatus. It is represented in Fig. 15. It consists of a series of twelve coils placed between two plates and turning between the poles of two permanent magnets. The coils of the electro-magnets are attached to one another; the entering end of each coil being connected to the outcoming end of the next coil, exactly as a series of voltaic elements are united in tension—that

is to say, the positive pole of each is connected to the negative pole of that following. When the plate turns in the direction of the arrow, supposing the pole N of the magnet the higher and the pole S the lower, this is what occurs in any given coil: as it

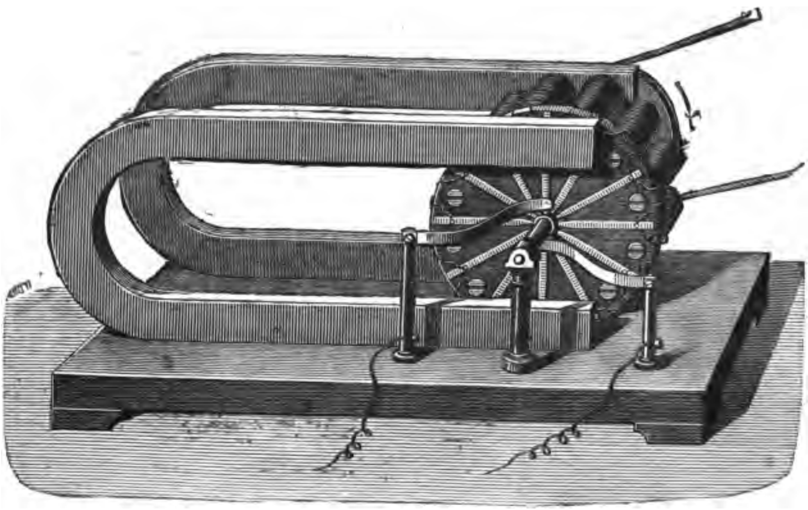

FIG. 15. NIAUDET'S MACHINE.

recedes from the pole N there is developed a current of certain direction, and this current remains of the same direction during the time that the bobbin goes from the pole N to the pole S, because the approaching of the pole S has the same influence as the receding from the pole N, and these two effects are concurrent. But during the second half-revolution of the coil, it recedes from the pole S and approaches the pole N, and consequently the direction of the current is inverse to that which it had at the first half of the movement.

Let us, however, see what occurs generally. At any given instant let us consider the bobbins placed to the right of a line drawn through the poles; these are all traversed by currents in the same direction, which are associated in tension. The sum of the currents to the right is then manifestly equal to that of the currents on the left-hand side. The whole may then be considered as two piles of six elements opposed to each other by poles

of the same name. Now if an electric circuit is put in communication by its two extremities with the points where these two series of elements are opposed, it is traversed by a current from both batteries, which are then associated in quantity.

By analogy, in order to collect the currents developed in the Niaudet machine, it is necessary to establish friction-pieces which touch the points of connection of the different coils at the instant these are passing the polar line. To this end, the inventor, imitating the Gramme machine which will be presently described, has placed metallic pieces which, directed radially, communicate with the points of juncture of the coils, and from these the currents are taken.

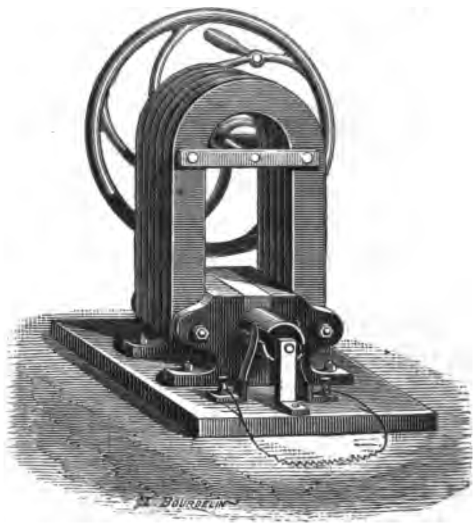

FIG. 16. SIEMENS' MACHINE.

The most important innovation that has been brought to bear on induction machines giving alternating currents is without doubt the construction of the longitudinal bobbin devised by Siemens and Halske, of Berlin, in 1854. The iron of this bobbin is cylindrical in form, hollowed out parallel to its axis in two large and deep grooves, so that its transverse section resembles a double T. The copper wire, insulated, is wound in

these grooves parallel to the axis of the cylinder, and is covered with a sheet of brass, which with part of the iron left uncovered, constitutes a complete cylinder. One of the ends of the wire is soldered to the metallic axis of the cylinder, and the other end is soldered to a metal ferrule insulated on the extremity of this axis.

Fig. 16 represents a Siemens machine with its bobbin. The armatures of the magnet embrace the bobbin very closely, and only leave play sufficient to permit of the rotation of the bobbin.

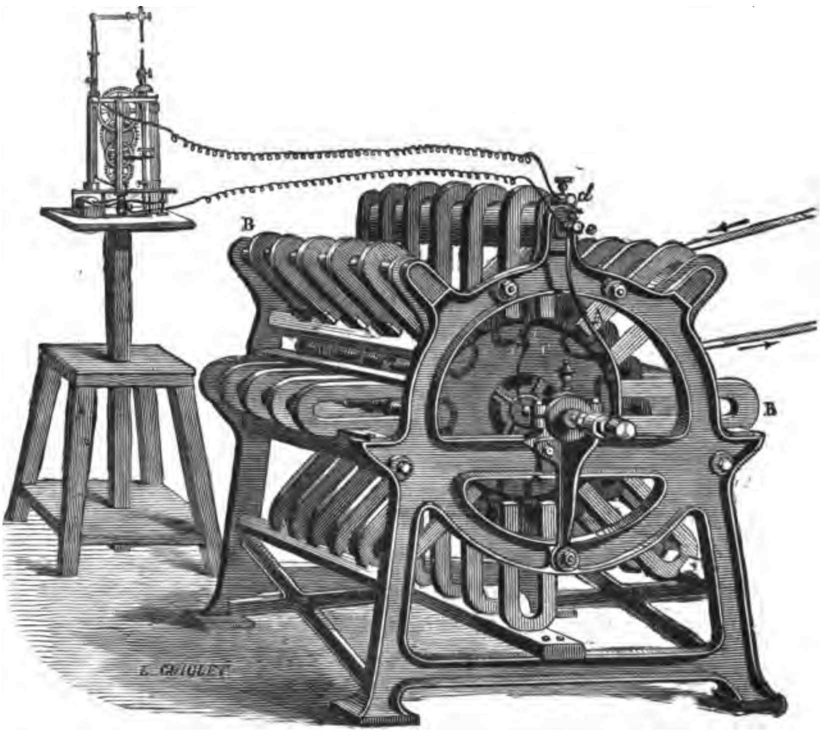

FIG. 17. "ALLIANCE" MACHINE.

This arrangement offers the advantage of giving the possible maximum of electricity and of preventing the magnets losing their power, for the bobbin acts as the iron keeper usually furnished to magnets to prevent loss of power.

The magneto-electric machine, now known as the "Alliance" machine, was invented by Nollet, professor of physics at the Brussels Military School. The object proposed by this inventor was to decompose water and to use for illumination the gas provided by this decomposition. Some considerable amount of capital was sunk in experiments on this chimerical idea, and the Alliance machine would probably not have been employed industrially without great perfection at the hands of M. Van Malderen, a pupil of M. Nollet.

This machine (Fig. 17) is constructed with a certain number of bronze discs C, each carrying at their circumference sixteen bobbins. These plates are mounted on a horizontal axle worked by a motor by means of a belt D, and they revolve between eight series of compound magnets B B, set radially around the axis and supported parallel to the plane of the disc by a special framework. As each magnet has two poles, one series presents sixteen poles regularly distanced. There then are as many poles as there are bobbins, so that when one is facing a pole the fifteen others are also facing poles. These machines usually have four or six discs, which consequently correspond to sixty-four bobbins and forty permanent magnets for one and to ninety-six bobbins and fifty-six permanent magnets for the other. One of the poles for the total current is attached to the axle, which is in communication with the frame by means of the bearings; the other pole terminates in a thimble concentric to the axle and insulated from it by a non-conducting substance.

The current changes its direction every time that a bobbin passes before the poles of the magnets. As there are sixteen magnet-poles there will be sixteen changes per revolution of the discs, and as the machine makes 400 revolutions per minute (more than six revolutions per second) there will be at least 100 changes of direction per second.

The important improvement previously spoken of is relative to the suppression of the commutator for the production of the electric light. This is indeed the simplification which has rendered the Nollet machine practicable, and admits of its application under numerous circumstances.

In two lectures by M. Le Roux before the *Société d'Encou-*

ragement are to be found most complete details on the theory, construction, working, and efficiency of the Alliance machine. These form the most complete and comprehensive work that has been published on this subject, and from this is taken the following explanation of the production of light with currents that are not redirected.

Because the direction of the current changes, and that a hundred times per second, it necessarily occurs that at each change the intensity of the current should pass zero. Thus one hundred times per second the spark ceases to play between the two carbons; one hundred times per second the spark ceases to exist. The light does not appear less continuous. This is due to the well-known persistence of light on the retina, and also to the fact that the voltaic arc, properly so called, only produces a fraction of the electric light, the remainder being due to the incandescence of the carbons, which incandescence does not cease immediately with the passage of the current. But as it is known that the currents employed have not sufficient tension, under ordinary circumstances, to throw the spark through the distance, that a mere breath will interrupt the voltaic arc, and that then extinction occurs until the points have been brought into contact and again separated, it is astounding that the cessations of current, occurring so great a number of times per second, do not lead to the extinction of the light. This fact is difficult to explain. The tension of the current is insufficient to cause the spark to play to that distance between the cold carbons; but when these are previously raised to incandescence by the passage of the current, the atmosphere surrounding them becomes better conducting by the elevation of temperature, and, doubtless also, by the presence of carbonaceous particles; the duration of the interruption being very short, the properties of the atmosphere surrounding the carbons have not time to become sensibly modified, and the current recommences to pass. The interruptions, admitting that the change of current may be accomplished whilst the centre of the bobbin traverses an arc of one millimètre, can have a duration of no more than the ten-thousandth of a second.

The poles of the lamp being alternately in contrary direction,

the two carbons are equally consumed. The electric light revolves, so to say, continually around the carbons, and successively illuminates every point of the horizon with very considerable variations of intensity.

The "Alliance" machines are employed at the Hève Lighthouse, at Cape Gris-Nez near Calais, at the Lighthouses at Cron-

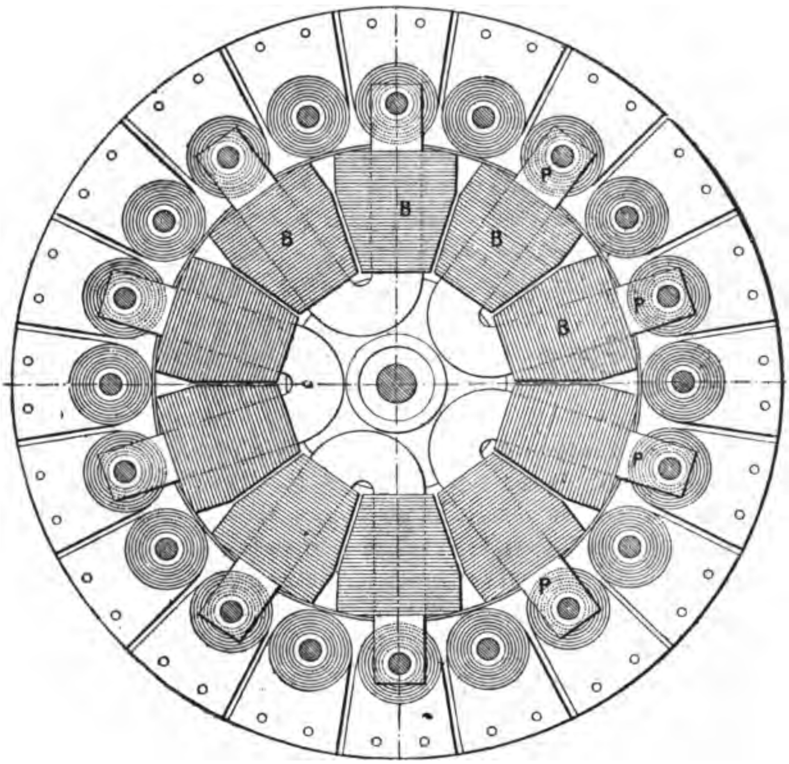

FIG. 18. HOLMES' MACHINE.

stadt, Odessa, &c.; they have been tried on several vessels and in several local industries. They work very well and require only small motor power. However, their use does not extend, even though the French patent has become public property, and others than the Company itself may construct the machines.

This position in particular of a good apparatus happens from

a multitude of causes which it is unnecessary to here recount. It may be said, however, that the price of these machines is too high, and the space they occupy too large for the obtaining of advantages industrially. It will be seen, indeed, in the chapter devoted to the cost price of electric lighting, the importance of the first cost of establishment and introduction of magneto-electric machines and their regulators. Everyone knows, on the other hand, how precious is space in the majority of manufactories or constructive workshops.

Mr. Holmes, an English physicist, who has given much attention to magneto-electric machines for the production of light, has patented several original arrangements, the most recent of which, 5th June, 1869, is represented in Fig. 18. Instead of revolving the coils before the magnets or electro-magnets, Mr. Holmes revolves the magnets or electro-magnets before the coils. He employs part of the current produced to magnetise the electro-magnets and couples the coils in such a manner that these can give several independent currents, and consequently produce several independent lights with the same machine.

Thus, instead of revolving the induced coils before the inductors, Mr. Holmes revolves the inductors and fixes the induced pieces. This is returning to the Pixii machine, which may have its advantages for certain applications, but has only a secondary importance in the majority of cases. We have described this apparatus in order to give an idea of the path followed by Mr. Holmes in his researches on electric lighting.

The analogy existing between the last machine and the "Alliance" machine is apparent. We have not taken account of the chronological order of the inventions, but it is useful to observe that the working of Holmes' machine is based on the use of the electro-magnetic exciting coils, and on the effects of *remanent* or *residual* magnetism employed before by several physicists.

The Exhibition of 1867 contained two extremely remarkable magneto-electric machines with alternating currents, about which we shall say a few words. These machines both come from England, and their inventors, Messrs. Wilde and Ladd,

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the first especially, are physicists who are universally known and appreciated.

The Wilde machine (Fig. 19) consists of two Siemens' apparatus superposed and of unequal dimensions, with the

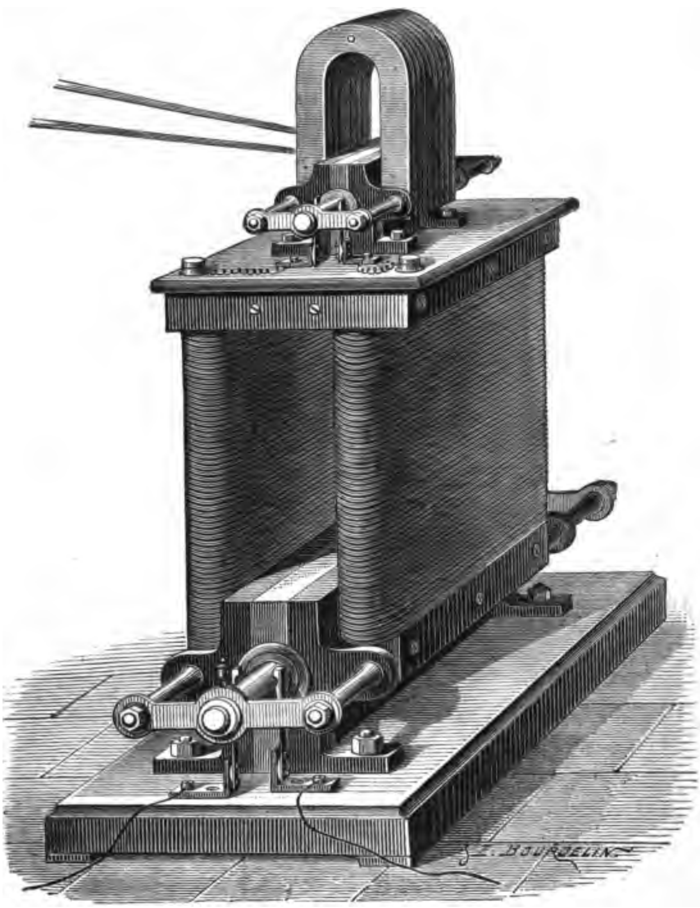


FIG. 19. WILDE'S MACHINE.

modification that, in the larger, the magnet is replaced by a powerful electro-magnet. The upper and smaller machine is intended to magnetise the electro-magnet; it is for this reason termed the *exciting machine.* Between the two arms of the

magnet revolves a longitudinal bobbin that developes alternating currents, which are redirected by a commutator and led to the electro-magnets by wires connected to two special terminals.

Beneath is placed the large electro-magnet: its two branches are constructed of large plates of sheet iron, and for the elbow of the horse-shoe is substituted a plate of iron carrying the *exciter;* the poles of this electro-magnet are masses of iron separated by a copper plate, and form a cylindrical cavity in which revolves the second Siemens' bobbin. This part of the apparatus is termed the *generator.*

The two bobbins are exactly similar; the diameter of the larger is three times that of the other. The exterior conducting wires are attached to its poles.

The insulated copper wire which covers the branches of the large electro-magnet are carried to special terminals of the exciter.

By the aid of two driving belts and a proper motor, the two bobbins are caused to revolve, the smaller with a velocity of 2400 revolutions per minute, the larger with a velocity of 1500 revolutions per minute. Thus the currents induced in the exciter maintain the larger electro-magnet strongly magnetised, and the currents induced in the generator are utilised in exterior work. Their intensity is considerably superior to that of the currents from the *exciter.*

This very remarkable arrangement presents considerable advantages to the preceding machines, especially with regard to chemical decompositions, in which its applications are in England very numerous. This would have also been the case in France if Messrs. Christofle and Co., who tried the Wilde machine and the Gramme machine simultaneously in 1872, had not recognised the superiority of the latter machine.

Siemens and Wheatstone have combined magneto-electric machines without permanent magnets, descriptions of which appear in the 'Proceedings of the Royal Society of London, 1867,' and which resolve the important problem of the conversion of dynamic force into electricity without the aid of permanent magnetism. Mr. Ladd, about the same time, invented the machine bearing his name.

Ladd's machine (Fig. 20) consists of two large straight and parallel electro-magnets, at the extremities of which are placed two Siemens' bobbins of different sizes. The small bobbin excites the electro-magnets, and these react on the large bobbin which furnishes the utilisable electricity. The wires from the

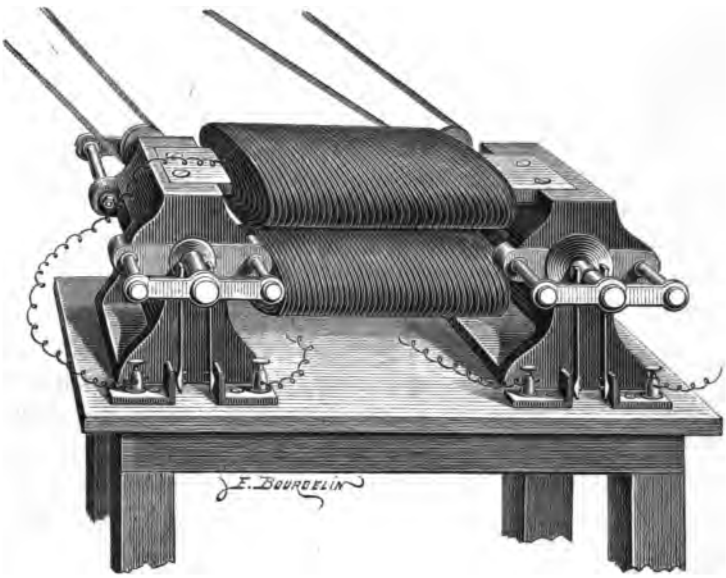


FIG. 20. LADD'S MACHINE.

electro-magnets are connected in such a manner that the contrary poles will be in relation when a single current passes. The free ends of these wires are carried to terminals where they receive the currents from the small bobbin.

The principle on which the Ladd machine is based, and characterising also those of Siemens and Wheatstone, is this: when a bobbin revolves between the poles of an electro-magnet, if this is the seat of a current, there is developed in the bobbin an induced current the intensity of which is proportional to the velocity and the magnetising power. If part of the induced current is employed to excite the electro-magnet, there occurs a similar state of things to what happens when the electro-magnet is excited by a special machine, as in the Wilde machine. And,

in the latter case, the machine being stopped, there always remains a little magnetism in the electro-magnets. This *remanent* or *residual* magnetism, however feeble it may be, gives rise to a slight electric current in the bobbin, which current, sent into the electro-magnet, increases its attractive power. The electro-magnet, becoming stronger, reacts on the bobbin, and the electric current increases more and more until it attains a maximum corresponding to the velocity of the bobbin and to the quantity of iron and of copper employed in the construction of the apparatus. Nothing can be more admirable than this multiplication of electricity, this reaction of effects upon one another, this transformation of work into electricity without other intervention than that of metallic pieces revolving before other metallic pieces.

In order that a similar machine may be put in operation, it would be natural to admit that the electro-magnets have received an initial excitation, either by a battery or by a second machine: this is what generally occurs. Siemens, however, was the first to remark the following: instead of using a battery to provoke the accumulative action of the machine, it suffices to touch the soft iron bars with a permanent magnet, or to place them in a position parallel to the magnetic action of the earth.

In practice it is not even essential to consider the position of the machine, because the terrestrial magnetism always acts slightly upon the electro-magnets, and a trace of magnetism suffices to originate torrents of electricity. The mind is lost in contemplation of the succession of discoveries completing one another, and showing that with apparatus of small dimensions an infinite source of electricity could be produced if matter could withstand infinite velocities.

There are still to be mentioned the two machines devised by M. Lontin, described in the journals of the last year. One of these is constructed with several bobbins mounted on an iron disc, which revolves before the poles of a fixed electro-magnet. The revolving part has the form of a star-wheel. The currents are collected as in the Niaudet machine.

It ought here to be said that M. Alfred Niaudet is the first who had the idea of revolving a series of bobbins before two

magnetic poles: the "Alliance" and Holmes' multiple machines have as many poles as bobbins, and as many current inversions as magnets, whilst the Niaudet machine has only two magnetic poles, and consequently a single inversion of current for each revólution of the axle.

Messrs. Niaudet and Lontin have realised this principle with some difference in the details. Thus M. Niaudet uses wooden plates and permanent magnets; M. Lontin, iron plates and electro-magnets; the first arranged his bobbins parallel to the axis, the second prefers to place them perpendicularly, &c., but both revolve a great number of bobbins before two poles.

Believing that the light is produced more advantageously with alternating currents than with continuous currents (which is opposed to the truth), M. Lontin has recently constructed a second machine having great analogy to that of Holmes, and it can, like that machine, feed several regulators simultaneously. We have not been able to procure photometric measurements of the light obtained, we are only able to affirm that the motive power employed is rather large with relation to the luminous intensity.

M. Lontin is a very energetic worker; he has already constructed a large number of magneto-electric apparatus and several regulators; he has taken out many patents during the last fifteen years; however, we do not know of a single application of electric lighting by these methods. Indeed, although we have found the difficulties so great, and so large the amount of time and of money required in the resolution of this problem, we are none the less surprised at the small practical success of the labours of this inventor.

The Gramme machine, the construction of which we are about to analyse, includes all the advantages of the preceding, and brings an element of the first order into the science of electro-magnetism.

CHAPTER V.

GRAMME'S MAGNETO-ELECTRIC MACHINE.

Success obtained with Gramme's Machine—Principle on which it is based—Analysis of Effects obtained with a Circular Electro-magnet—Action of Soft Iron on Copper Helices—Action of Permanent Magnets—Method of collecting the Currents—Partial Bobbins—Illustrative Machine—Vertical Machine for Electro-plating—Horizontal Machine for Electro-plating—Laboratory Machine with Jamin Magnets—Pedal Machine—Application to Medicine—Other Applications—Transmission of Motive Power to a Distance—Worms de Romilly's Machine—Pacinotti's Machine—Services rendered to industry by M. Gramme.

The machine invented by M. Gramme is essentially different from that of Clarke and, consequently, from all of those derived from it. The Gramme machine is a work apart, susceptible of the most varied applications, and the name of the inventor is at the present day known to and appreciated by all scientific men. As soon as the machine was actually realised, an English Company purchased the English and American patents, the *Société d'Encouragement* awarded a gold medal and a prize of 3000 francs, and a large number of manufacturers ordered the apparatus. Since four years ago, the date of the first application, success has been on the increase; the inventor has been rewarded at Lyons, Vienna, Moscow, Linz, and Philadelphia. Wherever the machine has been exhibited, it has had the advantage of captivating general attention. More than 400 machines with magnets or with electro-magnets have been delivered, and gradually demands are becoming more and more numerous. Electric lighting, which did not exist, industrially speaking, before M. Gramme's invention, is at the present day within the domain of things practised.

Principle of the Machine.

In order to comprehend the principle of the Gramme machine it is necessary to look back to the most simple magneto-electric

induction experiment that can be made; but there is required a more complete analysis of the phenomena than is ordinarily attempted. Let us consider (Fig. 21) a magnetised bar, A B, and a conducting helix in reciprocating movement. If the helix is brought towards the bar from its position at X, an induced current is produced. Let us examine what occurs when the bar enters the helix by a series of successive movements.

FIG. 21.

It is to be observed that to each of these movements corresponds an induced current, and that these currents are in the same direction until the helix passes the neutral line, that is to say, the middle M of the bar A B; and that they are then of opposite direction if the movement continues in the same direction from this point.

Thus, in the entire course of the helix on the magnet two distinct periods are to be distinguished: in the first half of the movement the currents are direct, and in the second they are inverted.

In a memoir by M. Gaugain, published in the 'Annales de Chimie et Physique' (March, 1873), from which this interesting analysis is taken, may be seen an elementary explanation of this phenomenon by assimilating the magnet to a solenoid.

If, instead of moving from left to right, as we have supposed, the movement is from right to left, everything occurs as before, with the exception that the currents are opposite.

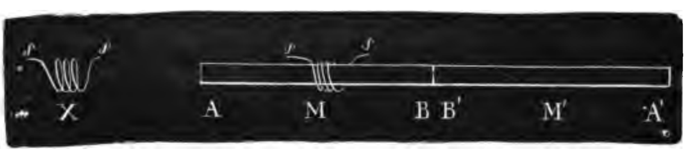


FIG. 22.

Let us, however, examine the complex case represented by Fig. 22. Two magnets, A B and B' A', are placed end to end,

in contact by poles of the same name, B B′. The whole forms a single magnet with a consequent point at the centre.

If the helix is moved with relation to this system it is evident from the preceding, that this helix is traversed by a positive current during the first quarter of the movement (between A and M) by a negative current in the second quarter (from M to B), again by a negative current in the third quarter (from B′ to M′), and finally by a positive current during the last quarter (from M′ to A′). Thus it is at these two neutral points that the current changes its direction.

By replacing the straight magnets by two semicircular magnets (Fig. 23) put end to end, the poles of the same name together, there occur the two consequent poles A A′, B B′, and the results are the same as in the preceding. The helix, in going from A to M, is traversed by a positive current, from M to B by a negative current, from B′ to M′ by a negative current, and from M′ to A′ by a positive current. The neutral points are then to be found on the line M M′, perpendicular to the polar line A B.

FIG. 23.

The essential part of the Gramme machine is a soft iron ring, furnished with an insulated copper helix, wound on the whole length of the iron. The extremities of this helix are soldered together, so as to form a continuous wire without issuing or re-entrant end.

The wire is denuded exteriorly, and the part bared forms a straight band running round the whole of the circumference. Friction pieces, M and M′, are applied precisely on the bared part of the helix.

When the ring thus constructed is placed before the poles S and N of any magnet, the soft iron is magnetised by induction, and there occur in the ring two consequent poles, N′ and S′, opposed to the poles S and N. If the ring revolves between the

poles of a permanent magnet, the consequent poles developed in the ring always remain in the same relation with regard to the poles N and S, and are subject to displacement in the iron itself with a velocity equal, and of contrary direction, to that of the ring. Whatever may be the rapidity of the movement, the

FIG. 24.

poles N′ S′ remain fixed in space, and each part of the copper helix successively will pass before them.

In considering an element of this helix, we know from what has preceded, that it will be the seat of a current of a certain direction when traversing the path M S M′, and of a current of inverse direction to the first when passing through the path M′ N M. And, as all the elements of the helix possess the same property, all parts of the helix above the line M M′ will be traversed by currents of the same direction, and all parts beneath the line by a current of inverse direction to the preceding.

These two currents are evidently equal and opposite; they balance one another. This is exactly what occurs when two voltaic batteries, composed of the same number of elements, are coupled in opposition. Now, in order to utilise batteries in opposition, it is necessary only to put the extremities of a circuit in communication with the poles common to the two batteries; then the currents from the two batteries are no longer in opposition, they are associated in quantity.

This is also the manner in which M. Gramme collects the currents developed in the ring of his machine. He establishes collectors on the line M M′, where the currents in contrary direction encounter each other.

If, in the case of two voltaic batteries in opposition, the extremities of a circuit are put into communication with the middle of each battery, instead of putting them to the common poles, the currents annul each other. Similarly, if the collectors of a Gramme machine are placed on the polar line, no current can be obtained.

We have so far analysed the action of the soft iron ring, magnetised by the influence of the permanent magnet, on the copper helix surrounding it; it remains to examine the effects produced directly by the poles of the permanent magnet on the bobbin, which, let us suppose, is left unprovided with iron and revolving as before.

Returning to the experiment of the magnetised bar acting in the copper helix, and removing this helix from the bar by a lateral movement, it is to be remarked that all parts of the helix with regard to the bar, as far as the centre of the helix, are in a certain direction, whilst the opposed parts are placed in inverse direction. The magnet will then create a current of a certain direction in the first half-helix, and a current of inverse direction in the second. The intensity of the first will evidently be superior to the intensity of the second, because the parts influenced are much more approximate to the magnet. The result of these two actions will be a very feeble current, which will naturally add itself to that we have previously analysed.

But when the iron is in the interior of the coil it will prevent the magnetism of the permanent magnet acting on the second part of the helix, and the total effect will be sensibly increased.

This is not all. The soft iron ring has also the effect of contracting the magnetic field of the permanent magnet, and of imparting to it consequently much greater inductive power. This is, according to M. Gramme, the principal cause of the production of currents in his machine.

In fact, the soft iron acts in three distinct ways: as inductor, as magnetic screen, and as exciter of the permanent magnet.

There are produced by the motion of the bobbin very complex direct effects, exerting on each other reactions still more complex; but the preceding notions will suffice, it is hoped, to give sufficiently exact ideas of the manner in which the currents are

created; this is the important point. A longer dissertation would fatigue the reader, and be without the province of this work.

There is now to be considered the method of collecting the currents.

It has been seen that by placing the friction pieces on a line perpendicular to the poles, there is obtained all the current developed in the bobbin, and that by placing these pieces on the polar line no current ensues. By placing the friction pieces near one another, always provided they are not put into a line parallel with the poles, the current will be feebler as the collectors are more closely approached, and this current will be in a certain direction, direct, for example, if the two receivers are in the parts M S and M′ N, and inverse, if the receivers are in the parts S M′ and M N. This is easily perceived by referring to the consideration of voltaic batteries.

It is, however, easy to see that several currents may be taken on the same ring, or several machines associated in tension or in quantity. Everything occurs as with voltaic batteries, and the currents obtained are of the same nature.

In practice, M. Gramme does not denude the wire of the ring; he constructs his apparatus in such a manner as to assure the stability and solidity necessary, especially for industrial application.

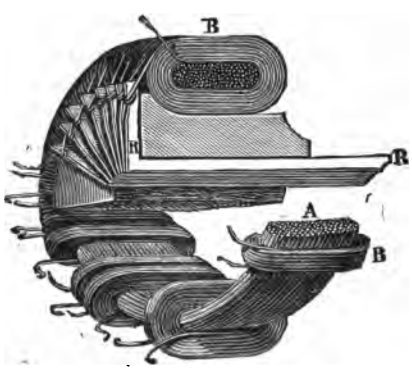


Fig. 25.

It is known that in certain straight electro-magnets, particularly those of powerful induction coils, the wire is wound in distinct bobbins placed side by side but connected in tension: in this manner is the wire distributed on the rings of the Gramme machine.

Fig. 25 shows the different wire and coils, which are the elements of this source of electricity, as voltaic couples are the elements of a voltaic battery.

To render the construction of this essential part intelligible, it is represented in section: in this view one or two coils, B, are shown in position, and also with the iron ring laid bare and cut.

Generally the ring A is made of iron wire, which gives a greater security, relatively to its property of becoming magnetised and demagnetised more quickly, without retaining magnetism when not under the influence of the magnet.

Radial pieces, R, insulated from one another, are each attached

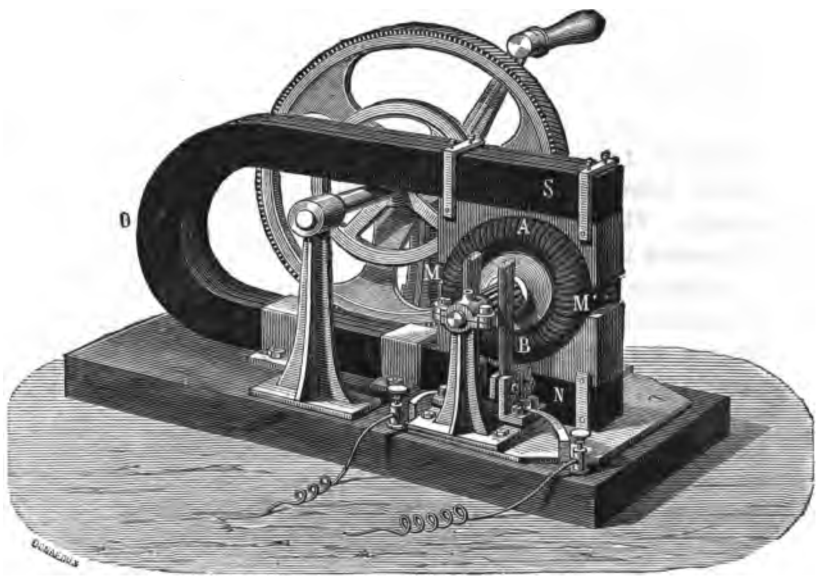


FIG. 26. MACHINE FOR ILLUSTRATION.

to the issuing end of a bobbin and to the entrant end of the following bobbin. The currents are collected on the pieces R, as they would be on the denuded wire. These pieces R are bent at right angles, and their second parts, brought parallel to the axle, are carried through and beyond the interior of the ring.

In the view (Fig. 26) it is to be seen that the pieces R are brought near one another upon a cylinder of small diameter, but always insulated by silk ribbons or other insulating material, interposed. It will be also noted that the friction brushes on

the pieces R are in a plane perpendicular to the polar line A and B; that is, at the middle or neutral points M and M'.

Reconsidering what has been said of the principle of the machine, it is easy to perceive that it will furnish continuous currents and that the direction of the current will change with the direction of rotation.

The continuity of the current manifestly results from the fact that the motion productive of electricity is continuous, and that the circuit is never interrupted, because the friction pieces or brushes commence to touch one of the pieces R before abandoning the preceding one, and their flexible and multiple nature always causes them to touch in some part if not throughout their whole width.

The intensity of the current naturally increases with the velocity of rotation; experiment has shown that the electromotive force, measured by opposition, is proportional to the velocity. This observation has been verified several times in France and in England, and also by the inventor.

According to the application in view, M. Gramme modifies his machine so as to produce effects of tension or of quantity by winding the ring with fine or coarse wire; it appears indisputable that with equal velocities of the ring the tension will be proportional to the number of convolutions of the wire; but the internal resistance increases in the same proportion, and in the majority of cases the best results are obtained by employing thick wires. It is, however, to be understood that, if the exterior circuit has a very high resistance, as in telegraphy, it will be better to employ machines with fine wire.

Before studying the machine used for lighting purposes and its numerous applications, we will rapidly review some types of Gramme machines intended for other operations.

The machines for electro-plating in use in the factories of Messrs. Christofle and Co., Ranvier, Mignon and Rouart, Desclairs, Folie, Olsanski, Poure and Blanzy, Wohlwill, the 'Société du Val d'Osne,' &c., give excellent results.

The first machine made by the inventor himself, in 1872, and delivered to Messrs. Christofle and Co., at Paris, has a bronze base, resting on a wooden sole. Its operation for five years has been to the entire satisfaction of the users. No repairs

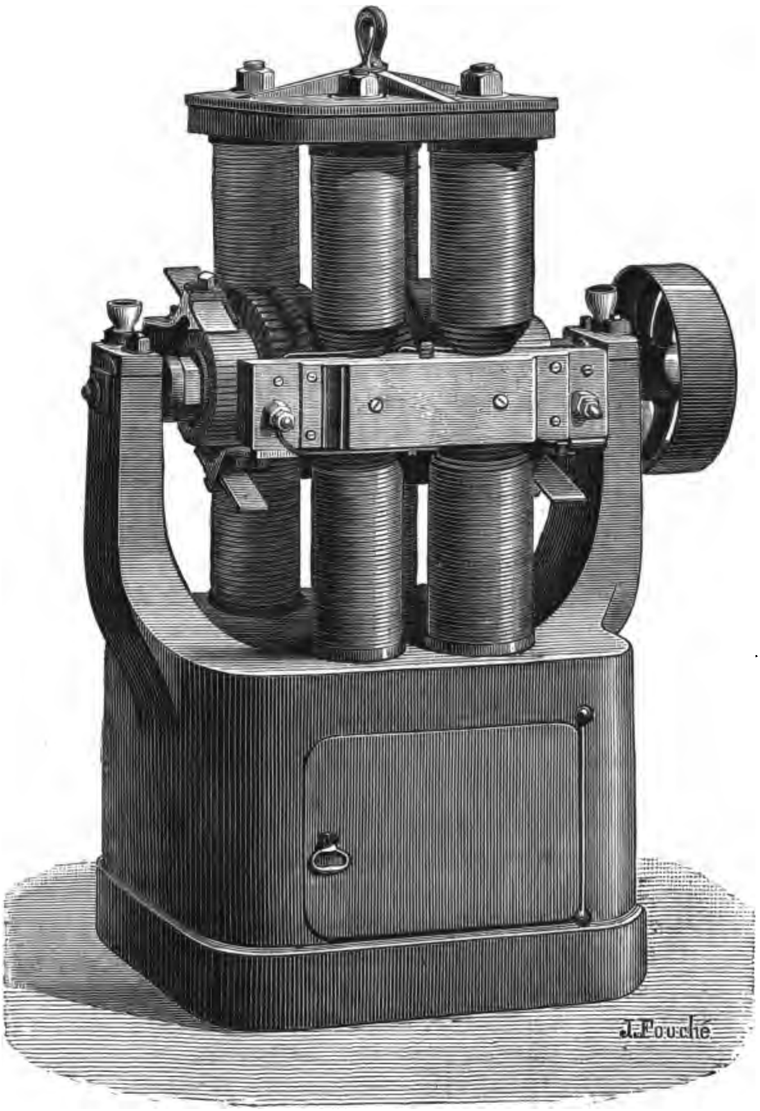


FIG. 27. VERTICAL MACHINE FOR ELECTRO-PLATING.

have been necessary, and all its expenditure is included in the cost of the oil for lubrication.

Without changing any of the electrical parts, the inventor constructed, towards the close of 1872, ten more machines with cast-iron bases as represented in Fig. 27, and Messrs. Christofle and Co. purchased six of these machines, which they have used since this time in their workshops.

These machines weigh 750 kilogrammes each, complete; they have four bar electro-magnets and two bobbins. The weight of copper entering into their construction is from 175 kilogrammes. Their dimensions are 1·30 mètre in height and 0·80 mètre in greatest width. They deposit 600 grammes of silver per hour and necessitate, for this deposit, a force of 75 kilogrammètres (exactly one French horse-power).

At the close of 1873, M. Gramme's calculations and experiments led him to combine a new type of machine for electroplating, much superior to the preceding.

This machine (Fig. 28) has in fact only one coil instead of two, and two electro-magnets instead of four.

Its total weight is 177·50 kilogrammes; the weight of copper on the bobbin and electro-magnets 47 kilogrammes. Its dimensions are 0·55 mètre in the side and 0·60 mètre in height. It deposits like the former machines 600 grammes of silver per hour. Its working is excellent in all points, as stated by Messrs. Christofle and Co. The motive force necessary to drive it is not more than 50 kilogrammètres.

Compared with the model of 1872, that of 1873 possesses the following advantages: (1) it requires only half the space for its introduction, (2) its total weight is reduced more than three-quarters, (3) the copper necessary to its construction is reduced nearly three-quarters, (4) it economises 30 per cent. of motive power.

These improvements have been obtained by the suppression of the exciting bobbin, by putting the electro-magnet in the same current circuit; by the better arrangement of the copper conductor both on the coils and on the electro-magnets, and by an increase of velocity which has no injurious effect on the regularity of working nor the duration of the working parts.

The conductor of the electro-magnets, formerly made with round wire, is now constructed, for electro-plating machines, of a single band of thin copper, taking up the whole width of a half-bar of the electro-magnet, so that this conductor consists really of only four bands, each forming a single helix.

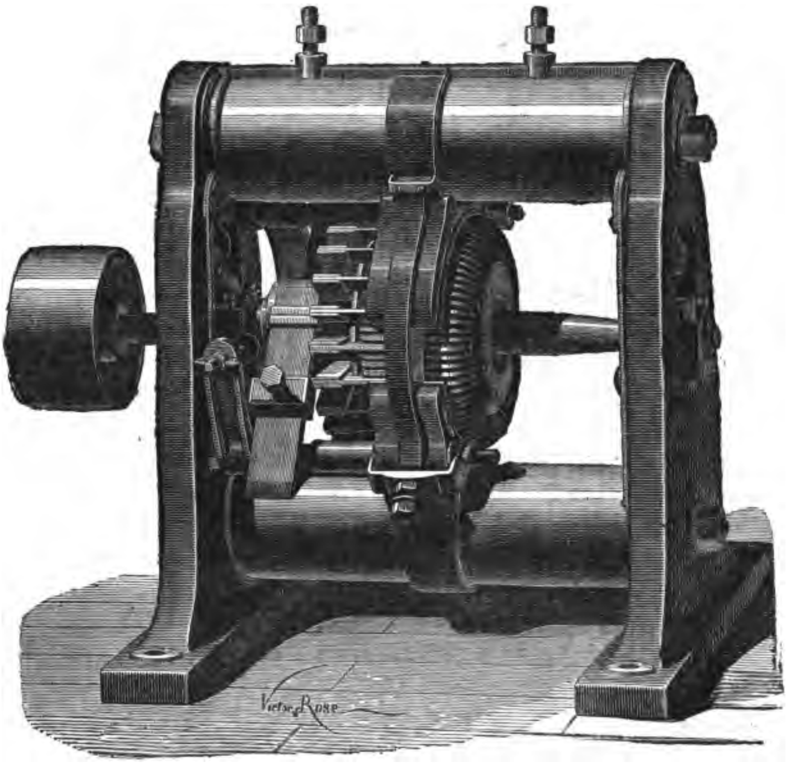


FIG. 28. HORIZONTAL ELECTRO-PLATING MACHINE.

The conductor on the bobbin is composed of a very thick flat-wise wire, offering sufficient rigidity to resist the effects of centrifugal force when the axle is caused to revolve at 500 revolutions per minute, whilst in the old machines the velocity did not exceed 300 revolutions. No sparks are produced at the contact of the metallic brushes and bundle of conductors soldered to the bobbins. Neither the ring nor the electro-

magnets become heated. The brushes are easily regulated, and may be withdrawn from contact even during working.

The base has great stability; the axle, but slightly loaded, is in steel; its bearings are of small diameter, which causes considerable diminution in frictional work. The armatures are solidly fixed to the electro-magnet bars, and embrace nearly the whole of the circumference of the bobbin.

The special arrangement, which consists in putting the electro-magnets in the circuit in order to suppress the exciting bobbin, has given rise to the unpleasant phenomenon of change of polarity during working; M. Gramme has remedied this defect by a very simple and practical apparatus.

When the machines are in motion, and their circuit is closed by metallic baths, the poles remain the same during all the time work continues, but so soon as a stoppage is made, either by accident or voluntarily, a secondary current is set up by the bath, as in the experiment with a Planté battery, as is well known. This current, traversing the wires of the electro-magnetic exciters, imparts to them a magnetism contrary to that they previously had; it results that the remanent magnetism, which should serve as a point of departure if the machine were put in operation without change of conductors, gives an inverse current, and the work is inverted; that is, in the case of silvering for example, if a strap should come off, perhaps on continuing to work, the objects in the bath would become desilvered. In order to obviate this serious inconvenience, M. Gramme has devised a means of cutting off the current automatically when the machine slackens in speed; he thus avoids secondary currents, which alone occasion the change of poles. When, after a stoppage, it is desired to continue working, it suffices to bring in contact with the electro-magnets a small metallic plate, termed a *circuit-breaker*, in order to reclose the circuit and to set the machine again in normal action.

The circuit-breaker, as applied to new machines, is a small movable piece with a counterweight which connects the metallic brushes to the electro-magnets; as soon as these electro-magnets are magnetised, they retain the circuit-breaker in contact; but when, from the machine diminishing in velocity,

the electro-magnets lose their attractive power, the counter-weight removes the circuit-breaker, and there is no longer electric communication between the central ring and the electro-magnets.

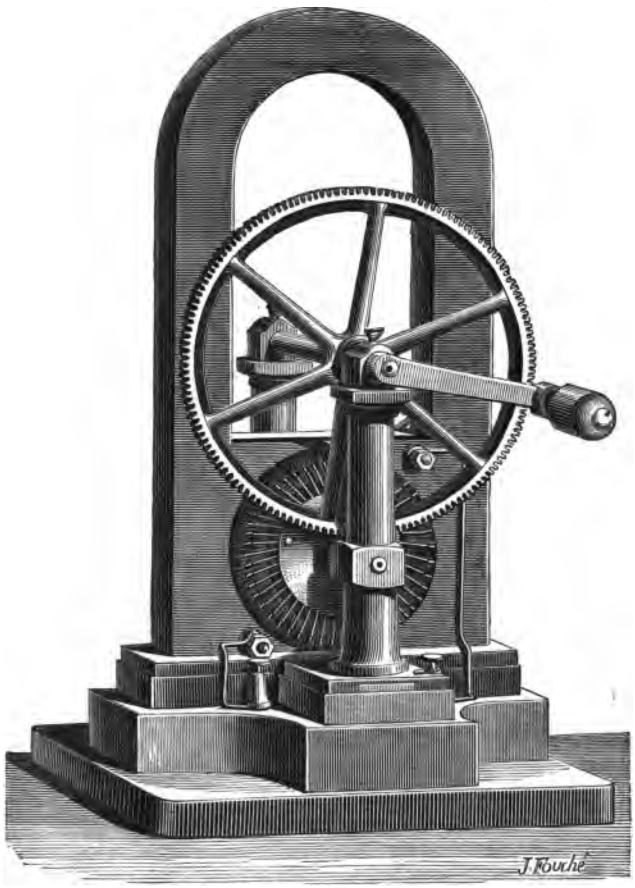


FIG. 29. MACHINE WITH ORDINARY MAGNETS.

No secondary currents can arise at the moment of stopping, and consequently the poles remain unaltered.

The construction of machines for experimental illustration has been confided to the celebrated house of M. Bréguet, at Paris, who has already furnished these apparatus to many of

the principal laboratories throughout the world. The first type of this apparatus was horizontal (Fig. 26); it gave a current equivalent to nearly three ordinary Bunsen elements. This was replaced by a more rational arrangement (Fig. 29), which, mounted with the excellent magnets of Allevart, produced the current of five elements without changing the bobbin. Since the invention by M. Jamin of laminated magnets, nearly all the laboratory machines have been constructed with magnets on

FIG 30. MACHINE WITH JAMIN'S MAGNETS.

this system. Some are turned by a wooden handle (Fig. 30), others with a pedal (Fig. 31). These machines are now equivalent to eight ordinary Bunsen elements. They admit of use in all the experiments of a physical course: electro-chemical decompositions, exciting electro-magnets, exciting induction coils, Arago's electro-dynamic experiments, &c.

All know that the inconvenience of mounting several Bunsen elements often deters the undertaking of an experiment in-

tended to be of only short duration. It may be added that the expense of mounting batteries is not wholly insignificant, whilst the muscular force of the experimenter or of his assistants

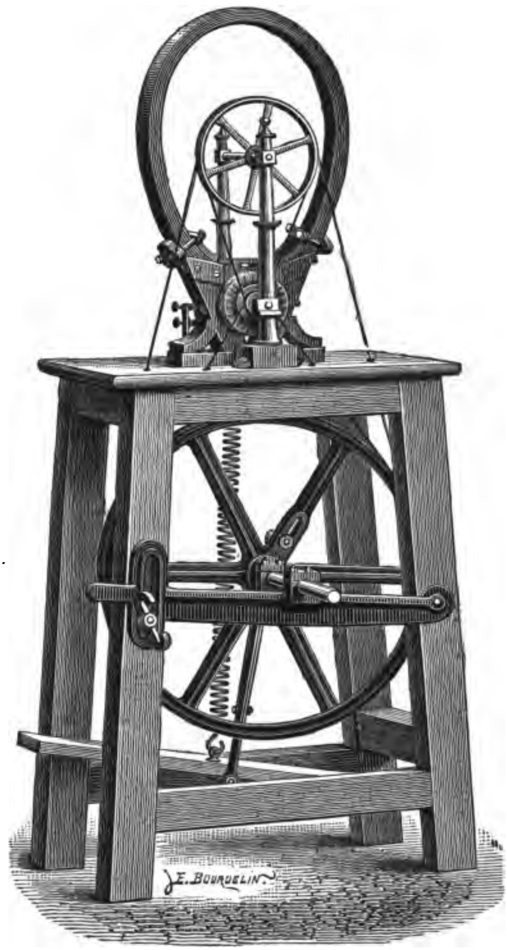


FIG. 31. PEDAL MACHINE.

is the only expenditure needed in the use of the Gramme machine.

Besides, there are some numerous advantages in having at

disposal a source of electricity that may be varied at will, and from which may be obtained by a "spurt," momentarily, much more than is given at the normal velocity.

The application to medicine is still more easy, and time alone is necessary to extend its usage; for the Gramme machine can, with some modifications, be employed in all cases where electricity is used in medicine. It can be applied to cauterisation by means of a platinum wire heated to incandescence. It also affords a means of chemically decomposing tissues where used in the resolution of certain tumours. It furnishes a continuous current and may be put in motion by the patient himself. It can be used to excite an induction coil, and may itself be used to give shocks by the simple addition of an interrupter placed on the axis of the ring; indeed, the extra-current from rupture of the circuit furnished by this machine has a very high tension, and as may be easily understood, because the machine consists of a wire wound a great number of times on a soft iron core.

Dr. Moret, of Paris, who has extensively studied the question of electricity applied to therapeutics, has declared, after having tried a small Gramme machine, that it united all the conditions wished for this employment, and that it would become finally a special manufacture, and universally an electro-medical machine.

We could not enter in detail into all the applications of which the Gramme machine is susceptible. M. Merle, at Alais, employs it for the purification of soda; Messrs. Collette have introduced it into a sugar refinery in order to withdraw the salts from the molasses and to collect the sugar; M. de Méritens uses it with success for his improved system of tanning; M. Wohlwill, of Hamburg, for the treatment of copper, &c. We cite only two of these applications.

M. Villiers, director of the Mining Company of Saint-Etienne, Limited, has invented a method of closing miners' safety lamps, so that the workers absolutely cannot open them, and the opening can only be effected by the lamp-man who is provided with a powerful electro-magnet. These lamps are very simply constructed: they are closed with a bolt; this bolt is placed at the bottom of a double cavity in the base of the lamp, so that the two poles of the special electro-magnet provided to the lamp-

trimmer can withdraw it, whilst neither the knife nor other process at hand to the miner can move it. This lamp has been in operation for several years; the lamp-trimmer's electro-magnet was formerly excited by a bichromate of potash battery, but this gave so much trouble, that M. Chauselle, chief engineer to the company, suggested the use of the Gramme machine. The machine is mounted on a table beneath which is placed a fly-wheel and a pedal; before the table are the two poles of the electro-magnet. The trimmer works the machine with his foot like a turner, and his hands are free to manage the lamps. Six or seven machines are in use at Saint-Etienne, and two at Monceau-les-Mines, at the works of Messrs. Chagot and Co.

To M. Lubery occurred the happy idea of employing electricity to automatically stop a knitting-loom, when a needle bends or a thread is broken; the application has been made to forty looms in the Works at Langlée, near Montargis, where a Gramme machine has replaced acids and batteries that gave the greatest trouble. For eight months the Gramme machine has revolved for ten hours per day at the rate of 1500 revolutions per minute without sensible wear. Instead of four workmen superintending the forty looms at Langlée as formerly, there is now only a man per workroom. Several millowners, notably those at Troyes, have also the intention of employing this important aid to the economy of labour indicated by this trial.

The Gramme machine, like all other magneto-electric machines, has for its principal purpose the transformation of mechanical force into electricity, but it can also transform electricity into motive power, and serve in this case as an electro-magnetic machine. It suffices to put any electric source in connection with the metallic brushes in order to put the central ring immediately into movement.

As very small motive power is equivalent to a large number of voltaic elements, it results reciprocally that it is necessary to use many voltaic elements to produce small mechanical work. It is this which explains the non-success of all inventors who have sought to produce motive power by electricity.

The continuous-current machine having neither crank nor dead-point, is eminently adapted for experiments on the trans-

formation of electricity into work, and it gives very high useful effect, as the following shows.

The inventor made (before us) the following experiment: A magneto-electric machine received motion from a steam motor, and required for its working an expenditure of force equal to 75 kilogrammètres measured by the brake; the electricity produced was conveyed to a second machine, which, also mounted with a Prony's brake, gave 39 kilogrammètres, that is to say, a little more than half the primary power. As the electricity passes through two machines, or, which comes to the same, as there was a double transformation of work into electricity and of electricity into work, each machine, although it had not been constructed for this purpose, had an efficiency superior to 70 per cent.

We have repeated the experiment with other electric motors, and we have never obtained an efficiency higher than 20 per cent. The Gramme machine is certainly the most perfect motor that has ever been constructed.

By means of two Gramme machines, motive forces could be very easily transmitted to great distances, and at the Philadelphia Exhibition there was shown a Neut and Dumont's centrifugal pump worked by a Gramme machine, which received electricity from a second machine actuated by a motor; but this is a new branch of application which has not been sufficiently studied to be considered as absolutely practicable from an economical point of view. It is a grand idea, which has only to ripen in order to open new horizons to a host of industries.

Like all great inventions, the Gramme machine has given rise to several claims for priority, and has immediately found imitators, more or less honest, and more or less happy. Of the latter we have nothing to say, because they have to the present done no good, and it is useless to publish their names, but we cannot pass in silence the claims of Messrs. Worms de Romilly and Pacinotti, which have been addressed to the Academy of Sciences.

M. Worms de Romilly constructed, in 1866, an analogous machine to that of M. Gramme, but instead of winding the copper wire on the iron ring always in the same direction,

M. Worms wound his partial bobbins in different directions; he was then compelled to redirect the currents produced.

M. Pacinotti constructed for the University of Pisa, in 1861, an electro-motor machine that was shown in the Vienna Exhibition of 1873, which is identical in principle with that of M. Gramme. M. Pacinotti even points out in the 'Il Nuovo Cimento' for 1864, that by reversing the operation of his machine, a magneto-electric apparatus could be obtained; only the design and the construction of this machine are so defective that it has never given good results, nor led to the supposition that its principle was superior to that of all other machines. It needed the appearance of the Gramme machine, in 1871, to remind M. Pacinotti of his idea, and to bring forward his claim, otherwise very just, from a scientific point of view.

M. Figuier relates, in 'Les Merveilles de la Science,' how eighteen years before the celebrated experiment by Œrstedt, relative to the influence of an electric current on a magnet, Romagnesi had remarked that *galvanism deflected the magnetic needle*, but no one then, neither Romagnesi nor contemporary physicists, foresaw the immense consequences of this discovery, whilst the labours of Œrstedt revolutionised the scientific world.

We add, with M. Figuier, that it is not rare to find in the history of sciences, analogous facts; great discoveries are sometimes, so to say, in the atmosphere, before a man falls in with them who comprehends their bearing and renders fecund the germ long since created.

Besides, it does not appear that M. Pacinotti had the first idea of circular electro-magnets; Dr. Page, of Washington, had, in 1852, constructed a motor which differs very little from that from Pisa, and which, far from being a simple laboratory instrument, was adapted to a locomotive, which it worked very badly it is true, but still worked.

It is not to be contested, that if the magneto-electric machines giving continuous currents now render immense services to electro-plating, to chemical decompositions, to lighting, and a multitude of other industries, this is really and solely due to the labours of M. Gramme. This inventor has, indeed, realised

industrially a principle pointed out by another physicist, a principle which had never been mentioned in any French, English, or German publication, and of which so little was known in 1869 that it was necessary that M. Gramme should again make the discovery in order to put it in practice.

M. Pacinotti, whose merit we do not in any way contest, sought to convert electricity into motive force, whilst M. Gramme occupied himself with the inverse problem. The views of the former were without horizon, limited to a path already found useless by many inventors; those of the other were immense, and fecund in useful applications. And it is precisely this difference in the end to be attained which is the cause of the failure of the labours of M. Pacinotti, while the Gramme machine commands public attention throughout the world.

CHAPTER VI.

GRAMME MACHINES FOR THE ELECTRIC LIGHT.

Vertical Machine with Six Bar Electro-magnets and Three Bobbins—Horizontal Machine with Four Electro-magnets and one Double Bobbin—Comparison between an "Alliance" Machine and a Gramme Machine, from the triple point of view of Weight, Displacement, and Price—Normal Type Workshop Machine—Photometric Measures—Difference between Measures taken at different Angles—Luminous Intensity from a Workshop Machine.

The production of the electric light requires a current of much greater tension than that used in galvanoplastic applications; also, instead of copper wires of large diameter or of thin bands of great width, M. Gramme has constructed machines with wire of small diameter, and he has considerably increased their velocity in order to resolve the problem of electric lighting. This high tension has been one of the most serious difficulties that the inventor has had to encounter in his practical studies; and it is only step by step, as the result of numerous tentative efforts, that he has arrived at a proper solution.

The first light-machine constructed by M. Gramme fed a regulator of 900 Carcel burners; its total weight amounted to 1000 kilogrammes. It had three movable rings and six bar electro-magnets. One of the rings excited the electro-magnet, the other two produced the utilisable current. The copper wound on the electro-magnets weighed 250 kilogrammes; that of the three rings 75 kilogrammes. The space necessitated was 0·80 mètre length by 1·25 mètre height.

This machine, which served for a long time for the experiments on the clock tower of the Houses of Parliament at Westminster, became slightly heated and gave sparks between the metallic brushes and the bundle of conductors on which the current was collected; this has, however, during five years, not given rise to any serious inconvenience.

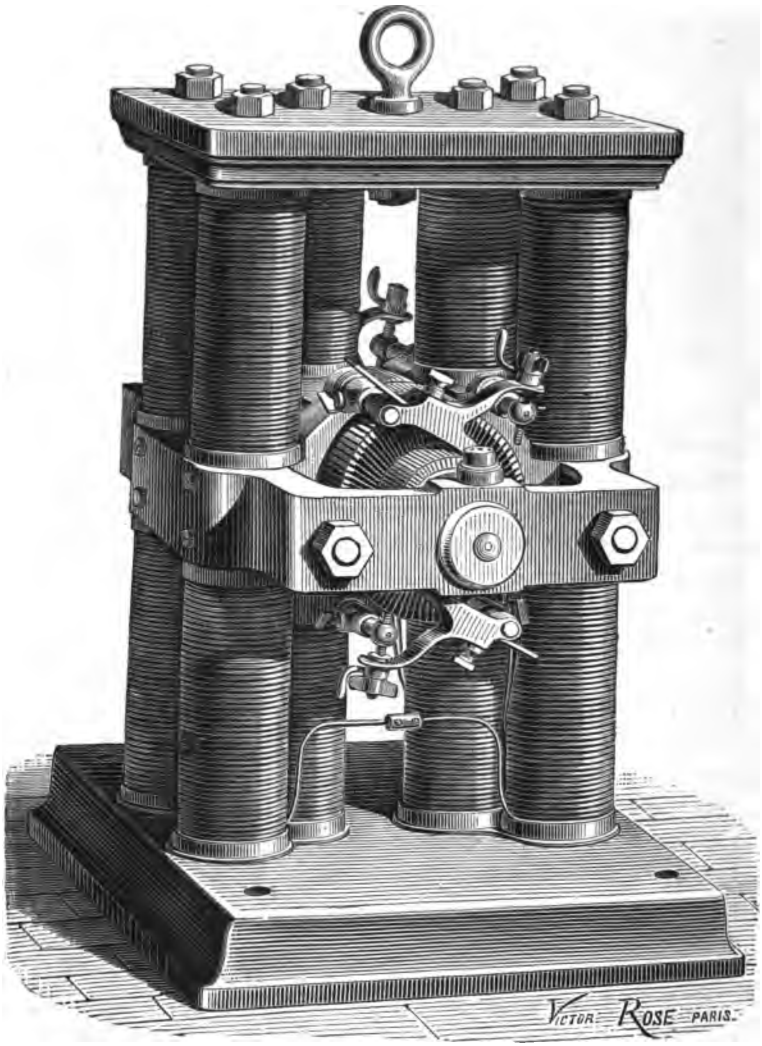


FIG. 32. VERTICAL MACHINE; 500 BURNERS.

Attempting better conditions, M. Gramme has always sought to suppress these sparks and the heating of the machine, and, as the intensity of the light then demanded by several governments did not exceed 500 burners, he was enabled to reduce the dimensions of the primitive apparatus.

We represent (Fig. 32) the first transformation. The machine has six bar electro-magnets; but, instead of being grouped on two right lines, these bars are grouped in triangles.

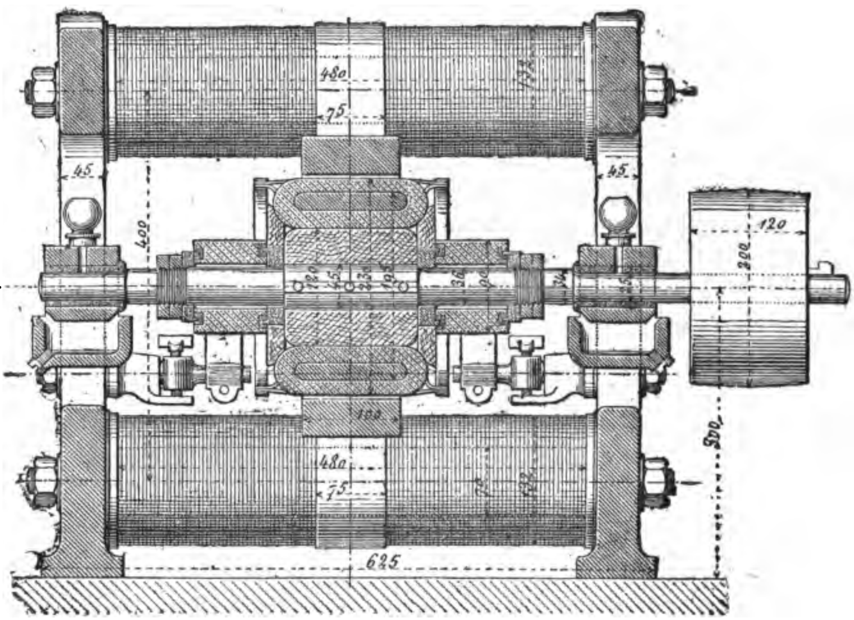


FIG. 33. 2000-BURNER MACHINE (LONGITUDINAL SECTION).

Two rings admit of conveying the total current into the electro-magnet, or of magnetising the electro-magnets with one of them, or of producing two separate lights.

This machine weighs 700 kilogrammes: its height is 0·90 mètre; its width 0·65 mètre. The weight of copper wound on the electro-magnet bar is 180 kilogrammes, that of the two rings 40 kilogrammes. It produces a normal light of 500 burners, which may be raised in experiments at great velocity to nearly

double. When a current is sent into two regulators, each will give 150 Carcel burners.

The apparatus thus constituted has been introduced on board the 'Suffren' and the 'Richelieu,' of the French marine; on the 'Livadia' and 'Peter the Great,' of the Russian navy; it is employed by several governments for service in fortified places. The velocity does not exceed 400 revolutions per minute. No inconvenient heating is incurred in the bobbin or in the electro-magnets. Briefly, the machine is excellent, but its price is somewhat high, and its luminous intensity slightly feeble when the atmosphere is foggy.

To remedy these two defects, the inventor has designed another machine (Figs. 33 and 34), which has given results much superior to all preceding it.

It consists of two flanks of cast iron, arranged vertically and connected by four iron bars, serving as cores to electro-magnets. The axle is in steel, of good quality; its bearings are relatively very long. The central ring, instead of being constructed with a single wire attached by equal fractions to a common collector, is formed of two bars of the same length wound parallel on the soft iron and connected to two collectors to receive the currents. The armatures of the electro-magnet poles are strongly developed, and embrace seven-eighths of the total circumference of the central ring.

The brushes, to the number of four, collect the currents produced.

The electro-magnet is placed in the circuit.

The total length of the machine, pulley comprised, is 0·800 mètre; its width, 0·550 mètre; and its height, 0·585 mètre. Its weight is 400 kilogrammes.

The double bobbin is connected to 120 conductors, 60 on each side. Its exterior diameter is 0·230 mètre. The weight of wire wound on is 14 kilogrammes. The electro-magnet bars have a diameter of 0·07 mètre, and a length of 0·404 mètre. The total weight of wire wound on the four bars is 96 kilogrammes.

The winding of the wires on the ring is so effected that there is precisely the same result as if two complete bobbins were put

one beside the other, and these two bobbins may be connected in tension or in quantity. Coupled in tension, they give a luminous intensity of 800 Carcel burners at 700 revolutions per minute; coupled in quantity, they give 2000 Carcel burners with 1350 revolutions per minute.

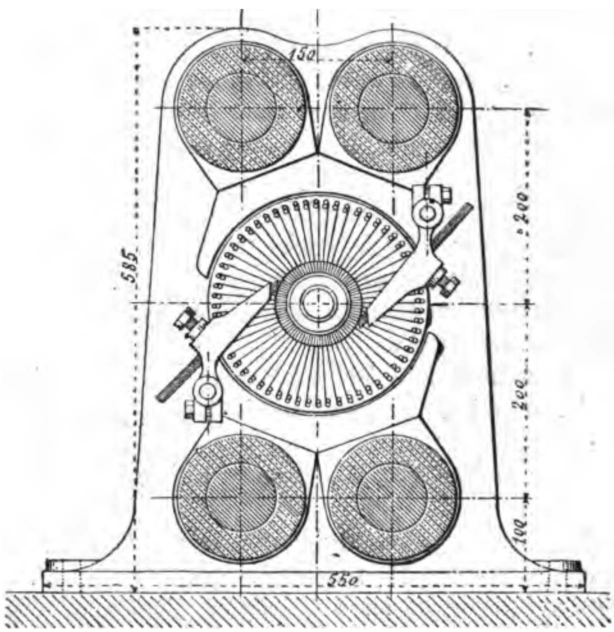


FIG. 34. 2000-BURNER MACHINE (VERTICAL SECTION).

This type of machine has been adopted by the Ministry of War in France, by the Austrian navy and artillery, by the Norwegian and by the Turkish Governments, &c. Wherever introduced it has given good results.

Comparison simply will lead to the appreciation of the perfection to which M. Gramme has in a few years carried magneto-electric machines for the production of light.

The "Alliance" machines, with six discs, introduced at the Hève Lighthouse, are 1·60 mètre in length (pulley included), 1·30 mètre in width, and 1·50 mètre in height. Their weight is

about 2000 kilogrammes. Their cost is 12,000 francs (=480*l.*) each. Their luminous intensity is 250 burners.

By considering the Gramme machine with four bar electro-magnets, and the "Alliance" machine of six discs, as both giving a lighting power of 100 Carcel burners, it is to be found that:

The "Alliance" machine has a weight of 800 kilogrammes, a volume of 1·20 mètre cube, and costs 4800 francs (192*l.*).

The Gramme machine weighs 20 kilogrammes, is of 0·12 cubic mètre volume, and costs 300 francs (12*l.*).

That is to say, the Gramme machine is 40 times more advantageous as regards weight, 100 times as regards volume, and 16 times as regards cost.*

By simplification upon simplification, the inventor has been enabled to introduce for industrial purposes a type of two-bar machine using only one central ring.

Fig. 35 represents the type definitely adopted for workshops and large covered spaces.

This machine weighs 180 kilogrammes, its height is 0·60 mètre, its width is 0·35 mètre, and its length, pulley included, 0·65 mètre.

The base weighs 120 kilogrammes, and is of 0·40 mètre height.

The copper wound on the electro-magnet bars weighs 28 kilogrammes, of which the ring weighs 4½ kilogrammes.

With so little copper and a velocity of rotation not exceeding 900 revolutions per minute, 1440 Carcel burners' light is obtained at a certain angle without any shade or projector, the axes of the two carbons being exactly in the same plane.

Before proceeding farther it is necessary to give some explanation of the method of taking photometric measurements, when comparison is made of the lighting power of an electric lamp and of an oil lamp.

When, to produce the electric light, a machine with alternating currents is used, the two carbons are nearly equally

* The comparison is made with the machines set up at Havre; it is possible that the "Alliance" machines have, since their introduction, been somewhat improved; but on the other hand, M. Gramme constructs a machine of 5000 burners, much more advantageous from the triple point of view of weight, volume, and price.

consumed. The best method then of evaluating the light is to place the two lamps and the photometer on the same horizontal line, because there is nothing to hide the flame of the oil lamp nor the electric focus. When two lamps are brought into use, there is much less light, but the ratio of the two sources remains very nearly the same.

On the contrary, in working with a battery or with a continuous-current machine, like a Gramme machine, the upper carbon becomes hollowed out and the lower carbon pointed; measurements taken horizontally cease to be exact, because the voltaic arc is partly situated in the small cavity of the upper carbon. It then becomes necessary to place the lamps at heights corresponding to those they will occupy in the localities in which they are to be used, and to take photometric measurements by inclining the photometer. The intensities varying with the distance at which the electric focus is situated, it is necessary to make a series of experiments when it is desired to accurately determine the lighting power of a machine. Practically, measurements may be made horizontally, taking care to incline the lamp at several angles, and to return the carbons vertically after each test. (This last precaution is requisite to prevent the carbons taking a bias; the arc always tends vertically.)

Sometimes the lamp is to be arranged in such a manner as to send all the light in front of it. For this it is sufficient to place the positive carbon slightly behind the negative carbon (their axes, for example, being apart by 0·003 mètre). The negative carbon continues to become pointed, but the positive carbon is burnt obliquely and forms a screen to the back of the focus and a reflector to the front. This artifice, which admits of the doubling of the effects of a projecting apparatus, is impossible with alternating-current machines, because these lamps have really no carbon that is especially positive or negative.

Although industrially it may be desired to know the intensity obtained with one or several apparatus, there is, however, little attention given to measurements taken horizontally in the laboratory, the question being the evaluation, as closely as possible, of the light utilisable. To this end we shall always, when defining the power of a machine, suppose the focus to be at five mètres

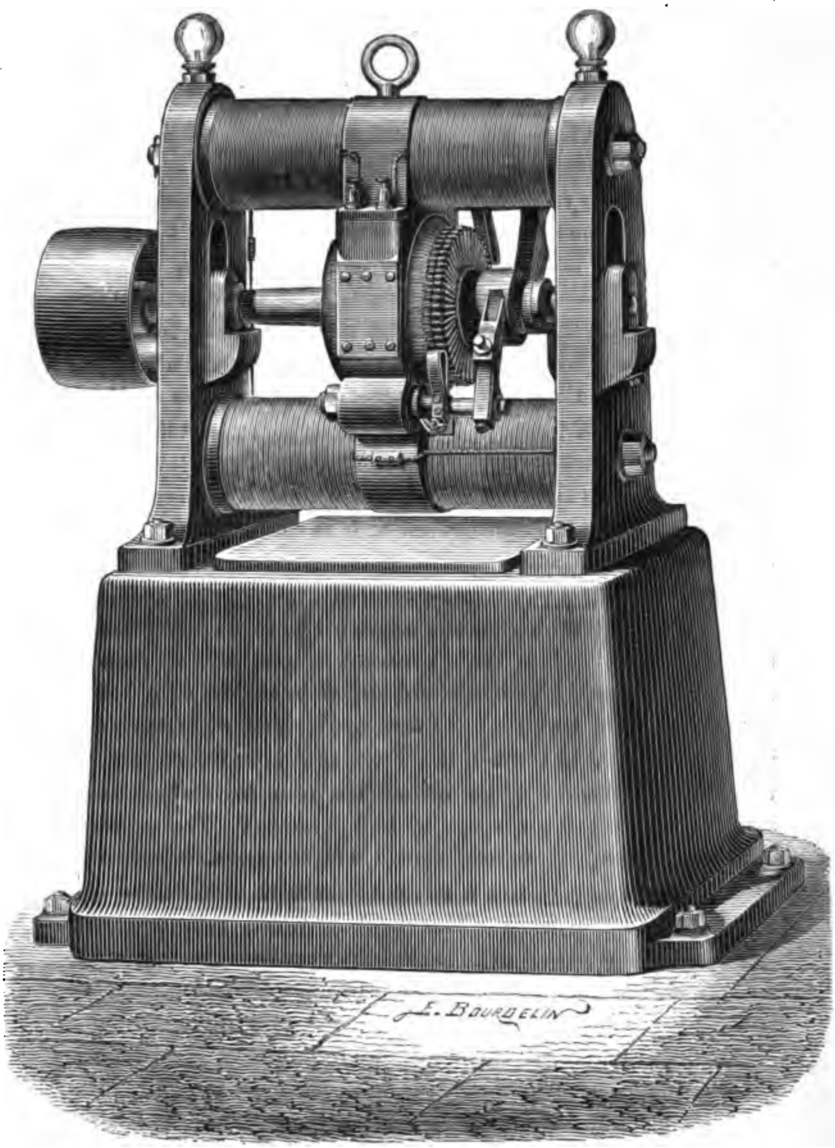


FIG. 35. WORKSHOP MACHINE (NORMAL TYPE).

height and the observer at 20 mètres in plumb-line from the lamp.

The following Table indicates the results obtained with a Gramme machine, of normal type, a Serrin lamp, and Gaudoin carbons (No. 1).

The motive power employed did not exceed two H.P., or 150 kilogrammètres, when the machine was making 820 revolutions, and three H.P. when making 900 revolutions. The electric lamp was placed at 25 to 200 mètres from the Gramme machine feeding it.

LUMINOUS INTENSITIES FROM A GRAMME MACHINE (Workshop type).

Number of Revolutions of Machine per Minute.	Distance of the Observer from the Lamp.	Height of the Lamp.	Number of Carcel Burners.	Remarks.
	Mètres.	Mètres.		
820	45·00	5	808	The distance apart of the carbons was not kept at 3 mm., because the tension of the current was too feeble.
820	22·50	5	450	
820	10·00	5	515	
820	5·00	5	600	
820	2·50	5	612	
870	45·00	5	400	Good tension; distance apart regularly 3 mm. Working satisfactorily.
870	22·50	5	550	
870	10·00	5	810	
870	5·00	5	1100	
870	2·50	5	1130	
920	45·00	5	452	Too great tension. The carbons heat for considerable length. The light is not steady.
920	22·50	5	704	
920	10·00	5	1207	
920	5·00	5	1420	
920	2·50	5	1440	

The intensities, measured horizontally with the lamp, electrical focus, and photometer in straight line, have for mean:

203	burners,	with a	velocity of	828	revolutions.
296	"	"	"	870	"
403	"	"	"	920	"

These results in the Table have not been obtained with a specially selected machine, but with several machines manufactured by Messrs. Sautter and Lemonnier and by Messrs. Mignon and Rouart. The intensities observed have not perceptibly varied, and did not in any case fall below 300 burners at

45 mètres distance from the regulator, or below 200 burners when the lamp, the regulator, and the photometer were placed horizontally in a straight line.

The mean of the light expended on a surface of 500 square mètres was 500 Carcel burners; at twenty mètres from the electric lamp the light equalled that from an oil lamp, with one-inch wick, at one mètre distance; at five mètres the light corresponded to that of an oil lamp at 0·55 mètre.

The motive power employed in these experiments did not exceed a half-horse power per 100 burners. The comparison of these figures with those obtained by M. Tresca, M. Hagenbach, and M. Schneider, shows the progress realised in this matter by M. Gramme in a single year.

By using an analogous machine and replacing the exterior resistance of the conducting wire by that given from galvanic baths, M. Gramme has obtained a relatively very considerable deposit of copper without diminution of the electric light. We note this remarkable fact without comment. A communication to the Academy of Sciences will shortly be made analysing the causes and importance of this point.

M. Gramme constructs a new type of machine, smaller than the preceding, the lighting power of which we have not yet measured.

We have still to mention a machine, intended to be exhibited in 1878, which will give the greatest luminous intensity with smallest motive force that has ever been obtained; a machine with multiple poles, intended to produce simultaneously several foci; but the cost will doubtless be higher than that of single machines giving the same total light; and a machine of eight powerful lights, made to order, and arranged for alternating currents.

M. Gramme, before his invention of a continuous-current machine, had deeply studied machines with alternating currents, and in his patent of 26th February, 1867, is to be found the first indication given in France of the possibility of interposing electro-magnets in the circuit of the coils.

CHAPTER VII.

INDUSTRIAL APPLICATIONS.

Necessary Conditions for use of the Electric Light—Spaces Lighted by one Machine—Introduction in the Workshops of the Inventor—The Ducommun Establishment at Mulhouse—Sautter, Lemonnier, and Co.'s Workshops at Paris—Ménier's Factories—Introduction in Spinning Mills—Chapelle-Paris Goods Dépôt—M. Jeanne Deslande's Yards at Havre—Luminous Ceiling—Mouth of the Marne Canal—Lighting a Skating Rink—Various Applications.

Lighting by electricity may be advantageously employed in a large number of works. It offers no practical inconvenience and admits of obtaining a great quantity of light at small expense. It is the only industrial illumination with which there can be executed by night as by day, the loading and discharging of cargoes, the mounting of machinery, carpentry, weaving, &c., and easy superintendence in a workshop attained. The light produced is in such abundance that, reflected from all the objects it falls upon, it is diffused in all directions like daylight; there is no part absolutely dark; it can be read by, and tools found by it, &c.

In spite of the luminous power of a focus, if work of a certain accuracy is to be done by it, it is indispensable to have two machines, so that the shadows produced by one light may be illuminated by the other; but then the extinction of light in each lamp necessary at the end of three-and-a-half to four hours' illumination is not a serious inconvenience; two minutes are sufficient to replenish the carbons in the lamp and to relight them, and during this short interval of time, the light from the other lamp prevents interruption of the work. Besides, if it is indispensable to have absolute continuity, there should be added to each lamp another for interchange, the lighting of the second lamp occurring automatically by the extinction of the first; but in practice this is not generally necessary.

Experience has shown that working by the naked electric light is not fatiguing to the eyes; after for some days using opal globes to temper the light, these were removed at the request of the workmen. The reduction of the light is unnecessary.

It is generally known that the electric light preserves the tints of colours. This property has been utilised with success by several dyers for standardising their colours by night; a single luminous focus of the very smallest dimensions is sufficient in this case.

When the ceilings are at less height than four mètres, the introduction of the electric light becomes more difficult, without, however, being absolutely impossible.

Generally, there may be conveniently lighted with a single apparatus, 500 square mètres of fitters' shops, lathe-shops, tool-shops, modelling-rooms, &c.; 250 square mètres in a spinning-mill, weaving establishment, printing-rooms, &c., and 2000 square mètres of yard, court-yard, dockyard, quay, and open-air works, &c. With these data, it is easy to calculate the cost of introduction anywhere, knowing that a complete apparatus, lamp, machine, conducting wire, transport and mounting, costs about 2400 francs (= 100*l.*) in France and its frontier countries.

Manufacturers who pay only 0·30 franc per cubic mètre, and find their establishments sufficiently lighted with twenty gas burners, should not seek a more economical light, unless they work all night without interruption; in which case it would be to their interest to replace ten gas burners by an electric apparatus.

The two questions to be examined are the cost price and the convenience. The second is often neglected, but this is wrong; because in the majority of cases, it is of the greater importance. We have had occasion to visit a large number of works, factories, and manufactories of all kinds in Europe and in America, and we have seen but few well-lighted establishments; few where a single more intense light would not have given easier superintendence, greater amount of work, and greater security. Fire insurance companies have so important an interest in the intro-

duction of the electric light, that several have offered to lower their tariff for all buildings thus lighted.

A rapid review of some introductions already made will lead to better appreciation than any possible reasoning as to the advantages of electricity.

The Gramme Company's Workshops.

The first permanent introduction of the electric light was realised in 1873, at Paris, in the workshops of the Gramme Company. The light was furnished from a single focus, which took the place of twenty-five gas burners. For four years its use has been regular and the cost price has not exceeded 0·60 franc per hour, including all expenses. The space lighted is about 12 mètres by 12 mètres and 5 mètres in height.

The Ducommun Establishment at Mulhouse.

In consequence of a visit to the Gramme workshops, Messrs. Heilmann and Steinlen, the present proprietors of the Ducommun factories at Mulhouse, decided to apply this new method of lighting upon a larger scale. For this purpose they placed in their iron foundries four Serrin lamps fed by four Gramme machines. The trial was crowned with success; during three years the working of the apparatus has been regular, and Messrs. Heilmann and Steinlen have the intention of extending this system of lighting to several other buildings.

The Ducommun foundry is of recent construction. It is well arranged for electric lighting without in any way being specially intended for this purpose. (The construction was entirely finished when it was decided to introduce the electric light.) It is a large hall without partition walls or vertical screens, of 56 mètres interior length and 28 mètres width. Two large travellers for the manipulation of castings and crucibles circulate from one extremity of the building to the other. At 5·5 mètres from the floor, level with the travellers, running along the two longitudinal sides, is a platform of some mètres width. The roof is a double incline, the joinery of which is slight, and the walls are lime-washed.

The Serrin regulators are placed on two light stands jutting out laterally from the platforms. Access is gained to them by a ladder, as with public lamps in gas lighting. The foci are raised 5 mètres above the floor; they are 21 mètres apart in the direction of the length of the building, and 14 mètres in the direction of the width.

The Gramme machines are placed in the engine-house with the machine employed for ventilation. The motor being larger than required for the work, alteration was unnecessary, and the ventilator and the electric apparatus are actuated simultaneously without inconvenience. The introduction has been very simple. The Gramme machines are placed on the first floor in one line, and they receive motion from a single intermediate shafting. All the parts are easily accessible, and the maintenance, which is reduced to some precautions in cleaning, can be effected during working, as well as when the machines are at rest. The motor is of the Sulzer type, its working is very regular, and the consumption of fuel small.

The lighting is generally constant in intensity; at any point of the place it is easy to read writing at normal distance from the eyes. There are nearly no shadows, because of the cross rays from the four lamps.

The complete introduction cost, in round numbers, 10,000 francs (= 400*l.*); which is about the cost of introducing 250 gas burners. The total light produced by electricity exceeds 400 burners.

We presently give the results of experiments made by Messrs. Schneider and Heilmann on the motive power absorbed by the machines, the lighting power of each lamp, and the cost of electric lighting as compared with gas lighting.

Messrs. Heilmann and Steinlen have obtained from the Gramme Company the right of manufacturing machines of a given type, and they have studied several arrangements to facilitate the use on ships and in war manœuvres. Fig. 36 shows one of these arrangements. It is a Gramme machine placed on the same sole as the steam motor and intended for introduction into sugar-refineries, on board ships, especially where steam is furnished by ordinary boilers, and where the

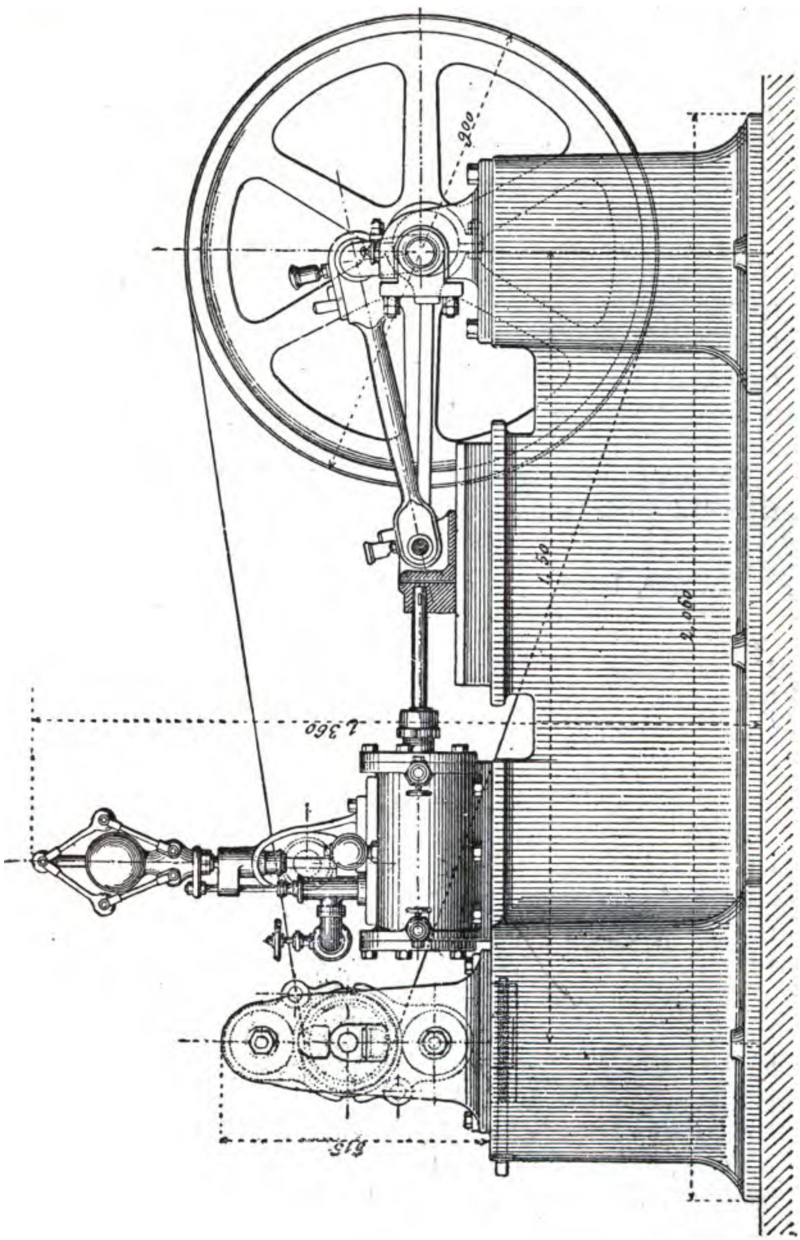


FIG. 36. GRAMME MACHINE WITH ITS MOTOR.

motor of the electric apparatus may be independent to ensure regularity.

To avoid all vibration, the sole is large, rigid, and well set. The total volume does not exceed 2·25 cubic mètres on 1 mètre. All friction bearings are calculated for durable service. The shafting of the steam-motor makes 150 revolutions per minute; that of the Gramme machine 850.

A rider, placed under the electric machine, admits of drawing it farther from the motor when the belt has not sufficient tension. This is an excellent means of preventing slipping of the belt, and consequently of ensuring regular velocity of the coil, but its use needs considerable care; an exaggerated tension of the belt absorbs much work and occasions greater inconvenience than the slipping itself.

The cost of the complete apparatus, motor and electric generator, is 4000 francs (=160*l*.).

Sautter, Lemonnier, and Co.'s Workshops at Paris.

Electric lighting is an important feature in the workshops of Messrs. Sautter, Lemonnier, and Co., the well-known makers of lighthouse-lenses, because no one than the members of this firm is more familiar with the use of strong electric lights, and, from the time of M. Gramme's first attempts, they asked and obtained authority to construct machines upon his system.

Its introduction into their workshops admitted that they could convince themselves and demonstrate to visitors that this method of lighting was excellent from all points of view, and that under certain conditions of local arrangements and for certain kinds of work, it is to be preferred to all others.

The Sautter and Lemonnier workshops consist of two buildings, each 30 mètres in length by 25 mètres in width; a platform, at 6 mètres from the flooring, runs between these buildings, with a width of 10 mètres. On the ground-floor are the machine tools, lathes, planing machines, drills, punching machines, shears, forges, &c.; the fitters there operate upon the larger work, and mount machines, &c. On the first floor are the model-makers, tinmen, and bronze-work fitters, with finer

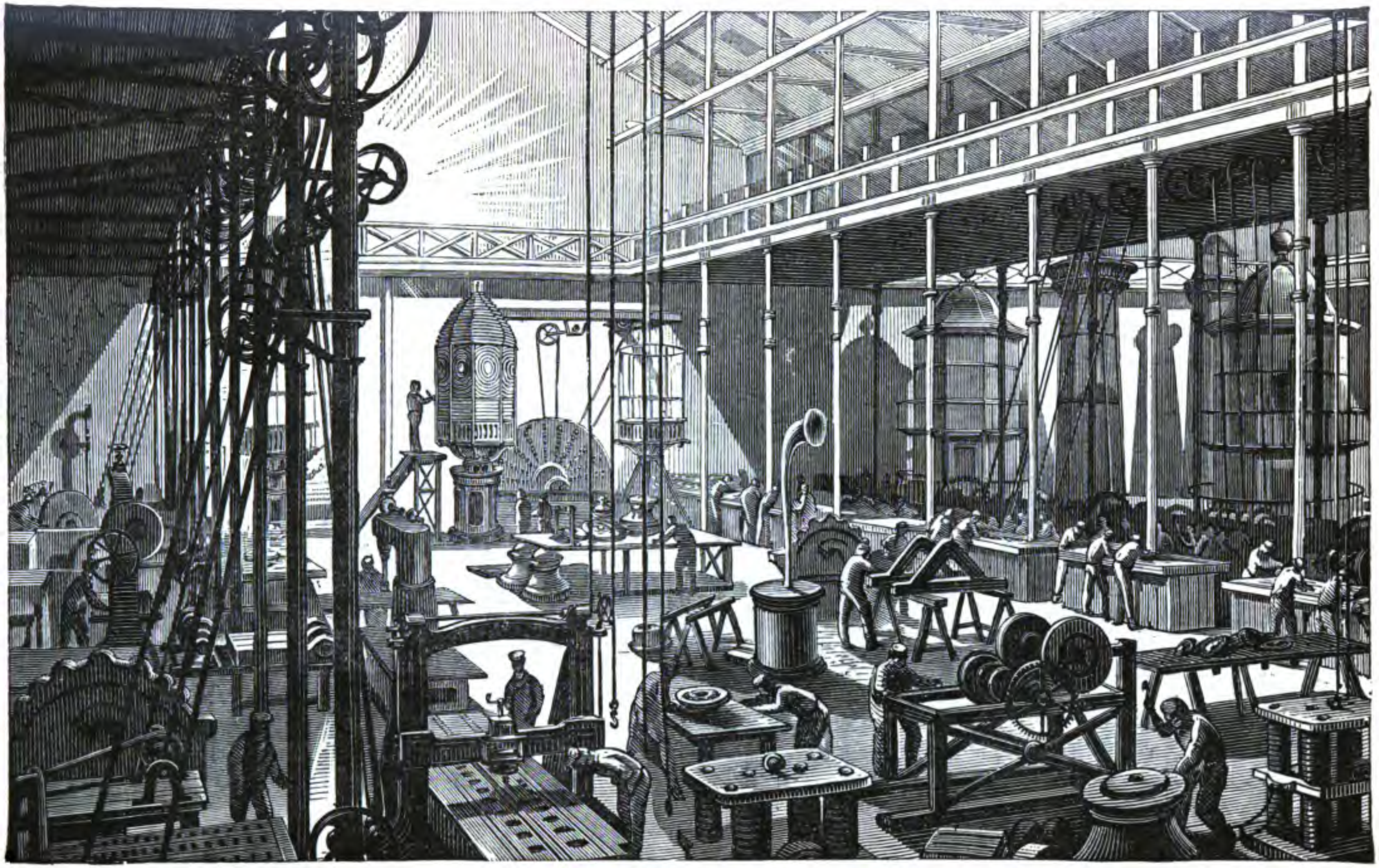


Fig. 37. Messrs. Sautter, Lemonnier, and Co.'s Workshops.

apparatus; three Gramme machines, giving each a light equivalent to 150 Carcel burners, illuminate the shops so effectually that all other methods of lighting have been removed, as well for operators with machine tools as for those doing finer work.

It might easily be imagined that in a shop of this kind the shadows thrown by the lathes, belts, and columns would be of great inconvenience to the work, and that especially where the light does not fall directly, the contrast would make the obscurity appear greater than with another method of lighting. This is not so. The light diffused, or, in other words, the light reflected by all points illuminated is such that there is not, properly speaking, at any part of the workshop a dark corner, and that the workman may easily distinguish objects at the bottom of his drawer.

The electric light, no more than any other, neither injures nor fatigues the sight of the workmen; they lose in a few days the habit of looking at it, and are very satisfied with a method of lighting that renders nightwork as easy as work by day.

A still stronger reason may be given with regard to superintendence, which can be exercised by night in a workshop lighted by the electric light absolutely as well as by day.

Intermittences are not to be feared, and this is the case in every workshop lighted by at least two lamps. When these lamps are well regulated, accidental extinctions are very rare. At the end of four hours' illumination, it is necessary to replace the carbons, and this operation is performed in two or three minutes.

Messrs. Sautter, Lemonnier, and Co. have found that each Gramme machine consumes work equal to about 2-HP; this and the carbons for the lamp form the only expenditure for lighting. The carbons are consumed at the rate of 0·07 mètre per hour, and cost 2 francs per mètre. 100 Carcel burners produced by this machine cost 0·14 franc per hour, in addition to the cost of motive power.

Fig. 37 is a view of the Sautter and Lemonnier workshops lighted by electricity. The engraving shows the whiteness of the ceiling and the uniform intensity of the lighting. It gives as exact an idea as possible of the remarkable effects of the voltaic arc in a closed and covered space.

Ménier Works.

M. Ménier has introduced the electric light in his various establishments, and has made good use of it in several particular arrangements. Since November, 1875, 14 machines, of 150 burners, have been in use, entirely to his satisfaction: 3 are set up in the sugar refinery at Roye, 3 in the caoutchouc factory at Grenelle (Paris), and 8 in the celebrated Ménier Chocolate factory at Noisiel.

In all these works, the lamps are so suspended as to admit of the renewal of carbons when necessary, without use of ladder or steps.

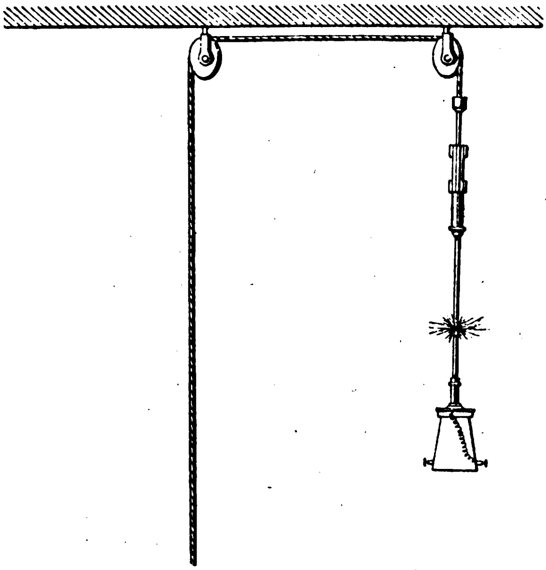
The roller represented in Fig. 38 is the invention of M. Henri Ménier. It consists of two cast-iron cheeks mounted on a hard-wood slab, and of a drum of vulcanite. The conducting wires are attached one to the left cheek, the other to the right cheek, and these communicate metallically with the extremities of the suspending cable.

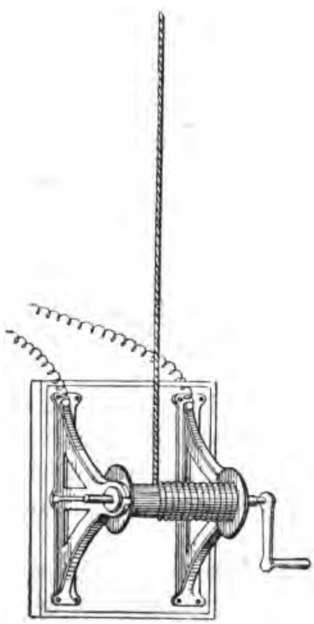
This cable is formed (Fig. 39) of an exterior covering of hemp, of a sheathing of caoutchouc, a series of copper wires braided like a wick, of a second sheathing of caoutchouc, and finally of a series of copper wires stranded into a cord, and forming the core of the cable. The winding on the drum is easily effected. A small ratchet prevents the lamp descending by itself.

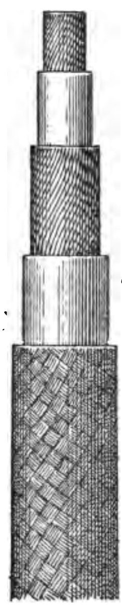
The cable, sustained and guided by two upper pulleys, is attached to a small plate which is connected to the lamp by two curved bars (Fig. 40). A frame, mounted with two lugs, is fixed to the lamp, and receives the extremities of the curved bars.

The current is led to the terminals of the lamp by the suspension bars, one of which is connected to the metallic core of the cable, and the other with its intermediate metallic part, that is to say, with the positive and negative poles of the magneto-electric machine.

The Noisiel works are lighted all night. The eight machines are coupled in two batteries of four. They are put in motion by hydraulic wheels, and, if necessary, when the waters are low, by







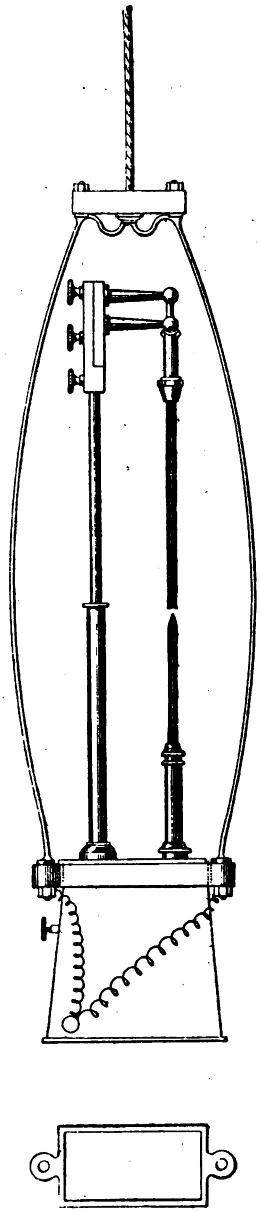


FIG. 38. FIG. 39. FIG. 40.

MÉNIER'S SYSTEM OF LAMP SUSPENSION.

a special steam motor. The wires are led to a commutator placed on the ground-floor (in the centre of several workshops), which admits of sending the current from each machine in fifteen different directions. By this means a room can be lighted by any machine, and the inconvenience arising from one of the machines or lamps getting out of order is entirely avoided.

Near each lamp is an interruptor, with which the lamp may be extinguished without stopping the motion of the machines.

At Noisiel the luminous foci are thus distributed:

A lamp placed in a square lantern and elevated 7 mètres above the level of the steam motor, lights a principal yard of 2000 square mètres surface.

Two other lamps each light an interior yard of 500 square mètres.

The torrefaction shop, where 32 operators work, is 44 mètres long, 11 mètres wide, and 7·70 mètres high; it is lighted by a single lamp placed in a glazed lantern on the ground, at one of the extremities of the workshop. The light is projected on to the ceiling by a parabolic mirror, inclined somewhat, and is thus diffused throughout by reflection. The weighing and moulding shop, where are 90 workmen, is 52 mètres in length by 11 mètres in width, and 7·70 mètres in height. It is lighted by two lamps placed at 25 mètres distance from each other, and suspended at 6 mètres from the ground.

The mechanics' shops are of 400 square mètres surface; these are lighted by a single lamp, suspended 6 mètres from the ground.

The grinding shops, which are 40 mètres long, 12 mètres wide, and only 3·60 mètres high, are lighted by reflection.

M. Ménier possesses, undoubtedly, the best system of electric lighting that exists in the world. He can, without any derangement, lead this light into his residence and light the hall, the large dining-room, the two drawing-rooms, the winter garden, and the gardens.

One lamp is specially intended for photometric projections and for scientific demonstrations in the lecture and conference hall.

On the occasion of the first distribution of prizes from the

School of Industry, M. Ménier gave, 20th August, 1876, a banquet of 1450 covers in a tent 65 mètres long, 32·50 mètres wide, and 7 mètres high. The banquet and the ball that followed were lighted in a fairy-like manner by six regulators of 150 burners. A lighthouse of 1200 burners, placed at some distance from the tent, illuminated the country for a radius of more than a kilomètre.

At the central sugar-refinery at Roye, M. Ménier has set up three Gramme machines with similar arrangements to those adopted at Noisiel. The first of these machines lighted the "carbonatation" room, which is 45 mètres long, 20 mètres wide, and 15 mètres high; the second is placed in the middle of the principal yard, where are the lime-kilns, stables, coal-sheds, &c.; the third lights the beet-root receiving depôt and washing-rooms.

At Grenelle, the caoutchouc factory has its large hall, where 150 persons work, lighted by three regulators suspended in a triangle at 6 mètres from the ground. The hall is 47 mètres long by 41 mètres wide. The machines are worked sometimes by the general motor, sometimes by a small special machine.

The three electric lamps replace 259 gas-burners, and produce, according to M. Ménier, five times more light than gas gives. At Grenelle, as at Noisiel and at Roye, the same system of raising the lamp by a cable with two conductors and the same arrangement of commutator is employed.

Spinning Mills.

Among the introductions of the electric light into spinning-mills may be mentioned those of Madame Dieu-Obay, at Daours; Messrs. Ricard and Sons, at Manresa, Barcelona; and those of Messrs. Buxeda Brothers, at Sabadell, Spain.

1. *Madame Dieu-Obay's Mills.*—The workshop is 3·70 mètres high, 43 mètres long, and 11 mètres wide. It includes nine double looms, with thirty needles, and seventeen spinning-mills, with fifty-two jockeys. Fifty persons, workmen and women, are employed.

The light is obtained by two Gramme machines worked by a hydraulic motor, which also actuates the looms.

The lamps are suspended at a height of about 2 mètres, and these are each furnished with a large lamp-shade reversed. This shade projects the luminous rays up to the ceiling, and these rays are thus dispersed in all directions. The focus is not visible, and consequently the sight rests on strongly illuminated, but not on incandescent, surfaces.

It has already been stated that the same artifice has been employed with success at M. Ménier's at Noisiel. The only special arrangement at Daours is in the height of the lamps, which is nil at Noisiel and mid-height at Daours. The result is very good in both cases.

Wherever there is a very white ceiling, and at a height of at least 4 mètres, there is an advantage in employing reflected light instead of the direct light.

2. *Messrs. Ricard and Son's Cotton Mills.*—The first floor of these mills is 33 mètres long by 21·20 mètres wide. Two lamps light ten self-acting machines. The Gramme machines are placed at the end of the workshop and are actuated by the general motor with an intermediate shafting. The height of the lamps is 3·40 mètres and their relative distance 15 mètres. We represent this arrangement (Fig. 41) because it is made under the very unfavourable condition of lowness of ceiling; it is the possible limit for good results, which it is requisite to exceed to preserve to the electric light all its advantages.

The second floor, the part occupied by the looms, is 16 mètres long by 21·20 mètres wide. A single lamp suffices. There are here five self-acting mules working all night, like those of the first floor, since May, 1876. The proprietors are very satisfied with their lighting.

3. *Linen Looms and Mills* (*Messrs. Buxeda Brothers*).—The room lighted electrically at Messrs. Buxeda's works is 58 mètres long by 22 mètres wide. It contains thirteen spinning-machines, twelve carding-machines, one loom, and some accessory machines. The lamps, three in number, are suspended at a height of 4·20 mètres, and distant from each other 13 mètres. There are four workmen to each spinning-machine, three to each group of two

carding-machines, and ten to the accessory apparatus; in total, eighty workmen in the same room.

With gas lighting certain work could not be done at night, because of the differences observed in the colours; now work is carried on night and day without stopping and without the least inconvenience in spite of the colour-tints.

The introduction at Messrs. Buxeda's was made six months ago (1877). The better quality of the products fully compensate the expenditure of motive power. The lighting itself is much more economical than that with gas or petroleum.

Chapelle-Paris Goods Depôt.

In consequence of experiments made in 1876 at the railway station in Paris, the Northern Railway Company decided upon the application of the electric light in the goods depôt, where work is going on all night. As it was necessary to establish a complete works, including building, motor, transmission, and the Gramme apparatus, it became more economical to light during the whole night, so that the interest upon expenditure might be spread over a great number of hours.

The spaces lighted included:

1. A hall, 70 mètres long by 25 mètres wide and 8 mètres high;
2. A shed, 70 mètres long by 15 mètres wide and 8 mètres high;
3. A yard, 20 mètres wide, separating the hall from the shed.

The hall is lighted by two lamps placed on the diagonals, and consequently unsymmetrically, which is very advantageous for this purpose. The lamps are elevated to 4·5 mètres from the ground and are enclosed in large square lanterns. The glasses of these lanterns are painted with zinc-white at the lower part, and to such a level that from no point in the hall can the eye perceive the voltaic arc and be thus affected. The upper part, on the contrary, is left clear, and the top of the lantern is not even glazed, whence it results that the upper luminous rays strike without any obstacle upon the ceiling and sides of the hall,

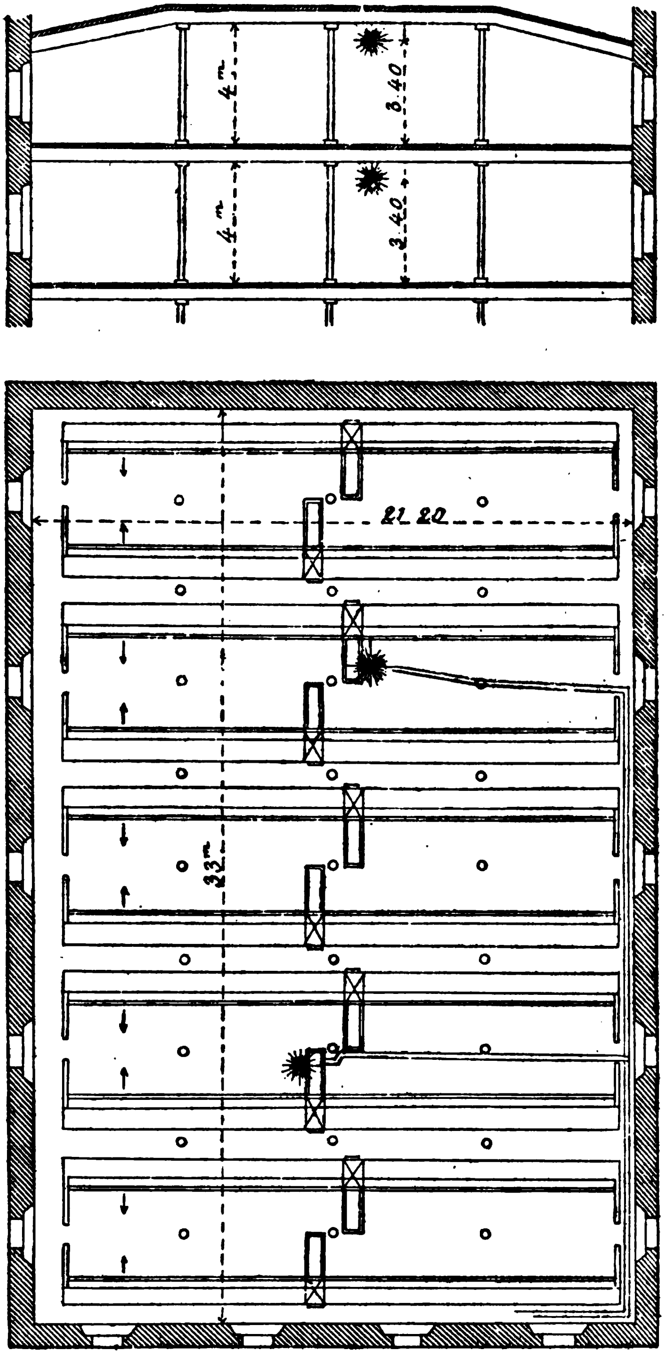


Fig. 41. Messrs. Ricard and Son's Cotton Mills.

thickly lime-washed, and are reflected as a soft and very uniform light.

The lighting of this hall was the principal object in view. It is very powerful, and this is necessary because of the keeping of small bales amongst the large, and of the number of tickets to be read. Writing is also necessary, to record the movement of the goods, which, arriving, are distributed and finally loaded into waggons brought up to the side of the depôt.

Everywhere in the depôt there is good light; in the office, the most distant parts of the space lighted, the small passages arranged between the voluminous bales, and despite their number; even in the bottom of the covered waggons which are loading there is sufficient light.

From a document which has been obligingly communicated with the authorisation of M. Sartiaux, engineer to the Company, we extract the following:

"The lighting has been in operation since the 17th of January, 1877, with a daily duration of fifteen and a half hours as a mean for the first months, and variable with the season.

"The great light diffused in the hall admits of the work being effected with greater celerity and less men. The economy in staff is valuated at twenty-five per cent.

"Every official has no longer need to carry a hand-lantern in order to search for the bales, decipher the addresses and marks, and read the lading-bills. The work is carried on at night nearly under the same conditions as by day.

"We have taken means to employ only two sheds instead of three for the service of the Company, which admits of economising the construction of a new shed.

"Besides those direct results the electric light has given the following indirect advantages, which reduce the indemnities paid by the Company. It reduces the errors in directions and the consequent delays, the damage in loading. . . ."

Let us add that it imposes obstacles to various frauds and reduces embezzlements.

The shed is lighted by a single lamp, and this is sufficient because there are only large bales to be handled. The lantern,

is similar to that in the hall. The lime-washing has been recognised as necessary here as in the other building.

The yard is lighted by the lamp from the shed, which is open on the longitudinal sides. The lighting throughout is at least as good as in the streets of Paris.

The average distance of the machines from the lamp is 80 mètres.

The expenditure is now estimated at 0·75 franc per hour and per lamp. This figure will be greatly reduced when double the number of lights are introduced, because the mechanic and the lamp-trimmer will suffice for a much more important lighting.

The cost of introduction is 25,000 francs, which includes the purchase of a steam-engine of greater force than is required. This expense would be but slightly increased by the addition of three new Gramme machines.

Detail of expenses for introduction:

A locomotive engine of 12 horse-power	7,900	francs.
Transmission, belts, &c...	4,348	„
Building	3,560	„
Lantern-towers, wires, and pulleys	793	„
Three Gramme machines	4,500	„
Four Serrin lamps	1,800	„
Total	23,000	francs.

Without exaggeration such a plant is worth 16,000 francs, because the transmission, the building, and the engine are 30 per cent. too dear, having regard, not to what has been done, but to what was really necessary.

Outer Port of Havre.—M. Jeanne Deslandes' Yards.

One of the most remarkable applications of lighting by electricity is that made on the building-yards of M. Jeanne Deslandes, at Havre.

This contractor is completing great works intended for the enlargement of the outer port of Havre and the creation of additional space for ships remaining in port.

These additions necessitate the demolition of considerable works, such as the curved quay and south pier as far as the

sea, the sluices of the Florida dock, the walls of the counterscarp, the clearing of the ground comprised in this vast extent, and the annexation of the greater part of the Florida dock to the outer port. They will give to the outer port a width of 185 mètres instead of 90 mètres, which is its present extent. The new area, including the Florida dock, will be 21 hectares instead of 11 hectares.

For the execution of the foundations, the driving of the piles, the demolition of the old walls, &c., it is only possible to work at low water; and in order that he might use the night ebbs, M. Chéron, director of the undertaking, has installed two Gramme machines, which have worked satisfactorily for six months.

Visiting in detail the works in course of execution, on a dark, starless night, we have found that men placed at distances varying from 20 to 120 mètres from the lamps could carry on all their ordinary work without the least inconvenience. The miners were piercing the old wall at 115 mètres from the nearest light and effecting the same amount of work as during the day. A locomotive, towing ten waggons, was running on a line of 1500 mètres, bringing materials right up to the works and transporting the rubbish to the assigned sites. A steam pile-driver was in action. Masons, carpenters, navvies, &c., were executing here and there works of every kind. More than 150 workmen, on a space covering 30,000 square mètres, were working without other light than that produced by the two Gramme machines.

The lights, enclosed in lanterns upon a platform of earth 5 mètres high, were in reality 15 mètres above most of the places where the work of construction or demolition was in progress. At 115 mètres we could distinctly read a newspaper, better than if it had been lighted by a gas-burner at a distance of 5 mètres. Each lamp gave a light exceeding 500 Carcel burners.

We earnestly advise engineers and contractors for public works to visit the arrangement of M. Jeanne Deslandes; there they will find the best existing solution of the problem of lighting works at night.

Messrs. Mignon, Rouart, and Delinières' Factory at Montluçon.

In their iron-tube works at Montluçon, Messrs. Mignon, Rouart, and Delinières have adopted two Gramme machines and two Serrin lamps for lighting one of the workshops. The building thus lighted is a hall 60 mètres long by 35 mètres wide. The lamps are placed at a height of 6 mètres and 31·5 mètres apart. The workmen can easily do their work and move and handle heavy pieces as well as during the day. The shadows of the columns or the machinery have so little effect that one can read even in the places where they are darkest.

In a second hall, adjacent to the first and separated from it by a wall with large openings through it, there is sufficient light from the electric lamps to enable one to read everywhere, even at a distance of 85 mètres from the lamps.

At Montluçon only Gaudoin carbons are used, these being found much better than the retort carbons.

Messrs. Mignon and Rouart, satisfied with this first application, are arranging to light completely with Gramme machines the new workshops which they have just erected on the Boulevard Voltaire at Paris.

It is complete evidence in favour of the system, that all those who have ever tried it extend its application to all places where it can be applied.

Luminous Ceiling.

It often happens that a large hall is badly lighted during the day, either because it forms part of a basement or because it is surrounded by other rooms intercepting the rays of the sun. In these cases, by means of a luminous ceiling, the hall can be illuminated by a white light, soft, and in all respects equivalent to sunlight. We have done this in one of the halls of the great warehouses of the Louvre at Paris, as shown in Fig. 42.

The compartment G is above and nearly over the middle of the room to be lighted. A regulator A, balanced by the counterweight C, is put in communication with a Gramme machine

driven by a portable engine and placed at 50 mètres distance from the ceiling. A plate-glass E, unsilvered and frosted, prevents the luminous rays from striking too directly into the hall and producing objectionable shadows. Four surfaces, F, forming a truncated pyramid, are lined with tin-plate, and

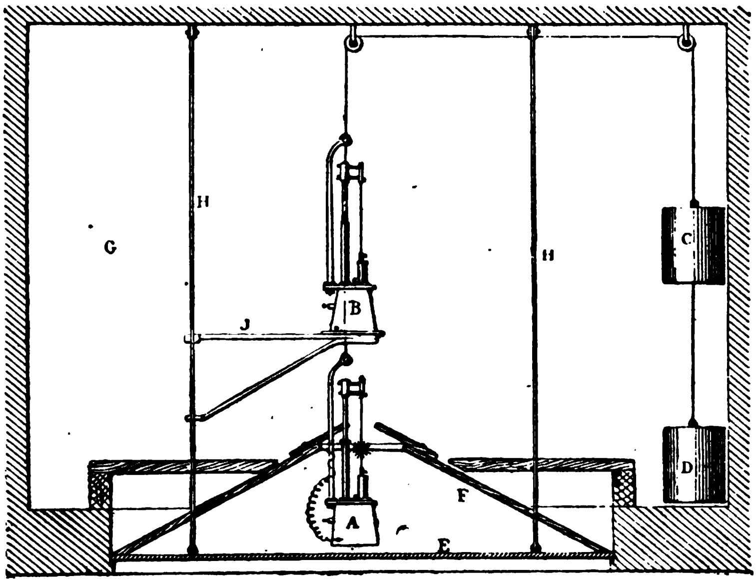


FIG. 42. LUMINOUS CEILING.

reflect downwards a great part of the light emitted by the regulator. Two rods H H support the frosted glass E. A second lamp B, resting upon a bracket J, and balanced by a counterweight D, is prepared beforehand, and replaces the lamp A when its carbons are consumed. Thus there is no interruption to the light.

This arrangement was made in February, 1877, and it has not ceased to work since that time. In consequence of the temporary engine not having a very regular speed, and the carbons of the regulators not being homogeneous, there are to be observed small scintillations and sensible variations in the luminous intensity; but this inconvenience is only temporary, it

will disappear completely when the proper engine is used and the Gaudoin carbons are substituted for those now employed.

The Marne and Rhine Canal at Sermaize.

Electric lighting was adopted, about the end of 1875, at one of the wharves of the Marne and Rhine Canal at Sermaize, contiguous to a sugar works. It was desired to continue during the long winter nights the unloading, if then urgent, of the beet-root boats, and to take the contents immediately to the factory, without storing them on the bank of the canal, which it was important to keep quite free for traffic. This special problem was solved by a Gramme machine of 200 burners, placed beside one of the engines of the factory, at a distance of 70 mètres from the lamp. The workmen, who frequently unload two boats at the same time, can work without the least inconvenience. This has been certified by the engineer of the canal and the manager of the sugar works; the latter has written to say that he was quite satisfied with this lighting, that the Gramme machine had attained admirably the object proposed, and saved him at least 10 francs per hour.

It may be mentioned that in the sugar works the expense of electric lighting is almost limited to that of the carbon rods for the lamps, because the steam which has driven the engine can be utilised after its discharge.

Lighting a Skating-Rink.

The Skating Company of Vienna (Austria) has established lighting by electricity in their large rink near Park Ring. This is the most successful open-air arrangement that has been made abroad. The surface of the ice is 5700 square mètres; the length of the space lighted, including the promenade, is 133 mètres; the total width is 57 mètres.

The light is furnished by two Gramme machines, each costing 3000 francs, placed at 135 mètres from the rink, and worked by a portable engine of 8 horse-power. The lamps are of the Serrin type. They are placed at the top of two fir poles, 7·50 mètres

high. They are 57 mètres apart. Two reflectors prevent the waste of light upwards, and concentrate all the rays upon the surface of the ice. For this purpose, the eight segments which compose each of these reflectors are curved to an elliptical form, having one of the foci at the luminous point, and the other 1 mètre lower.

All parts of the space are very well lighted, and altogether the arrangements are most satisfactory.

It is to be remarked that no other system could give so good a result, because the principal condition for a skating-rink is that its centre should not be encumbered by a series of posts. It is, besides, well known that gas undergoes great variations in the open air, and that a very great expense would be involved in lighting by it a space of 5700 square mètres.

The best proof we can give of the success of this application is, that the Skating Company, who had hired the apparatus, have now purchased them.

Various Applications.

We might describe many other applications, but the preceding will doubtless suffice to make the services rendered by electric lighting fully appreciated. A summary of some important applications will complete this chapter.

The cannon foundry of Bourges has eleven complete apparatus for its different workshops; Cail's manufactory at Paris has three electric lamps lighting an erecting shop of 5000 square mètres; the Mediterranean Ironworks and Dockyards Company has seven Gramme machines in its Havre workshops; the engineering works at Pantin have four complete apparatus. The works of Messrs. Crespin and Marteau, at Paris; Beaudet, at Argenteuil; Thomas and Powel, at Rouen; Ackermann, at Stockholm; Avondo, at Milan, &c., are likewise provided with Gramme machines.

We may also mention the works of Fives-Lille and of Tarbes; the engineering works of Barcelona; the Stations du Midi at Brussels; the ironworks of Fourchambault; the foundries of Bessèges and of Fumel, &c.

The quality which the electric light possesses of maintaining

the tints of colours has been utilised in many manufactures, notably in the dye-works of Messrs. Guaydet and Son at Roubaix, and in those of Messrs. Hannart Brothers at Wasquehall. Messrs. Hannart have stated that they can dye pearl-greys by the electric light, and that their production has notably increased since the adoption of the Gramme machine.

We have established lighting by electricity in the workshops of M. de Quillacq, at Anzin; the weaving shop of M. Baudot, at Bar-le-Duc; in the laundries of the Lyons hospitals, &c. More than 100 new applications are ordered: a great number are now being completed.

CHAPTER VIII.

APPLICATION TO LIGHTHOUSES, SHIPS, AND FORTS.

Application to Lighthouses—La Hève Lighthouse—Report of M. Quinette de Rochement — Different Lighthouses lighted electrically — Lighting the Transatlantic Company's Steamer 'L'Amérique' — Report of Captain Pouzolz—First Trials by the "Alliance" Company—Lighting on board the 'Livadia' — Sautter's Projector — Applications to Military Operations — Experiments made on Mount St. Valérien—Mangin's Projector—Portable Machine worked by a Brotherhood Engine—Gramme Machine capable of doubling its light instantaneously.

The electric light is employed with success in lighthouses, on ships, and in military engineering operations. It renders visible at night, at distances varying from 2000 to 6000 mètres, objects such as buoys, ships, coasts, houses, men, earthworks, &c. It allows the establishment of a telegraphic correspondence, either by direct transmission of the light from one post of observation to another, or, when it is not possible for two stations to communicate directly, by reflection on an object visible to both.

Application to Lighthouses.

The electric light was, in 1863, for the first time applied to lighthouses. The trial was made with an Alliance machine, at the first-order lighthouse of La Hève, near Havre, and the results were so satisfactory that, without doubt, all lighthouses would have been immediately provided with electric lights but for the great expense involved in a general change. It has been stated that the electric light was seen at least 8 kilomètres farther than the oil-light, and that in foggy weather the range of the light was twice as great with the former as with the latter.

M. Quinette de Rochement, a civil engineer, published in 1870 a note upon the lighthouse from La Hève, of which the following are some extracts:

"Since the electric light was established six years ago at La Hève, a sufficient time has passed to allow an exact idea to be formed of the value of this mode of lighting coasts.

"Sailors gratefully acknowledge the great services rendered to them by electric lighthouses; the advantages of the system have been keenly appreciated; the extension of the range of the light is very marked, especially in rather thick weather; it allows many ships to continue their course and to enter the port at night at a time when they could not have done so if the lighthouses had oil-lamps.

"The light, which at first left a little to be desired in respect of its variability, has gradually attained a remarkable steadiness, thanks to improvements in the apparatus and experience acquired by the attendants.

"The fears that had been entertained, *à priori*, as to the delicacy of certain apparatus, have not been realised in practice. Accidents have been rare, the extinctions short and few in number; only two during this period of six years have had any notable duration; one, for an hour, caused by an accident to the steam-engine; the other, for four hours, seems to have been attributable to malice. Under these circumstances there seems to be no reason to apprehend possible accidents."

There are now electric lighthouses in France, England, Russia, Austria, Sweden, and in Egypt. Everywhere their action is satisfactory. Hitherto in all these lighthouses there have been tried magneto-electric machines of only 200 Carcel burners, but we know on good authority that the French Administration of lighthouses, anxious to remain the first in the course which they have laid out, are about to experiment with a Gramme machine of 2000 burners. Without doubt, this machine will sensibly enhance the advantages already recognised for electricity over oil, and will perhaps determine a radical transformation in the existing illumination of lighthouses.

Lighting Ships.

To make the advantages of electric lighting on board ship well understood, we will first reproduce the article published

last year in the 'Moniteur de la Flotte,' and we will then give some information as to the application to the navy:

The packet 'L'Amérique,' belonging to the 'Compagnie Générale Transatlantique,' has since the end of March, 1876, been provided with a Gramme machine and the apparatus necessary for the production of the electric light.

The application under our direction, with the assistance of Messrs. Sautter and Lemonnier, is due to the personal initiative of M. Eugène Périère. The Gramme machine was constructed by the inventor himself, on an essentially new type. All the details of the project were previously submitted to M. Audenet, chief engineer of the 'Compagnie Transatlantique,' who aided us greatly with his advice.

The experiments, managed with as much skill as ingenuity by Captain Pouzolz, during the first voyage from Havre to New York and back, were crowned with complete success. M. Pouzolz on his return presented to the Council of Administration a circumstantial report upon the advantages of the system, and the Company immediately ordered a similar apparatus for the packet 'La France,' on the line from Havre to New York, and an apparatus on a smaller scale for 'La Ville de Brest,' on the line of the West Indies.

Thus shortly three ships of the Compagnie Générale Transatlantique will be furnished with electric lights.

The chief object of applying the electric light to navigation is to increase safety by avoiding collisions and facilitating the entrance to ports. It also admits of loading and manœuvres of all kinds being effected on a dark night as well as in broad daylight.

The apparatus on board the 'Amérique' comprises a beacon, a generator of electricity, a portable lamp, and various accessories.

The beacon is placed upon the top of a small iron-plate turret, which is ascended by internal steps, without the necessity of passing along the deck, as the turret is immediately above the hatchway of a staircase. This arrangement is of great advantage, especially in bad weather, when the fore part of the ship is accessible with difficulty by the deck. The turret was origi-

nally 7 mètres high; M. Pouzolz has had it reduced by 2 mètres to give it greater stability, and to lower the level of the luminous beam, so that now this turret is 5 mètres above the deck. Its diameter is 1 mètre. It is fixed in the fore part of the vessel, 15 mètres from the bow.

The lantern has prismatic glasses; it can illuminate an arc of 225 degrees, leaving the vessel almost entirely in shade. The electric regulator is on Serrin's system. The apparatus is suspended according to Cardan's method; a small seat at the top of the turret is provided for an attendant to regulate the lamp.

The luminous beam is about 0·80 mètre in depth.

The Gramme magneto-electric machine has a power of 200 Carcel burners, and weighs 200 kilogrammes; it is driven by a three-cylinder Brotherhood engine. The average speed is 850 revolutions a minute both for the machine and the engine (their shafts being simply coupled). The space occupied by the machine and engine does not exceed 1·20 mètre in length, 0·65 mètre in breadth, and 0·6 mètre in height.

The wires which connect the beacon or the movable lamp to the generator are well insulated. The total section of the wires has an area of 0·00016 square mètre. The Gramme machine and its motor are placed on a stage in the engine-room about 40 mètres from the beacon.

All the wires pass through the captain's cabin, who has under command commutators by which he can produce or extinguish at will the light in each of the lamps either alternately or simultaneously without stopping the Gramme machine.

The novelty of the arrangement in the 'Amérique' consists in the automatic intermittence of the beacon light. This intermittence is effected by a small and very simple mechanism fixed at the free end of the shaft of the Gramme machine. By means of a special wire, however, the captain can keep the light of the beacon continuous, but this is quite exceptional, for generally the flashes and obscurations constantly alternate. The Gramme machine continues to revolve constantly, but the current goes alternately through the carbons of the beacon lamp producing the light and through a closed metallic circuit which becomes alternately heated and cooled. A drawing would be necessary

for the proper explanation of the interrupting mechanism; we may, however, give a sufficiently clear idea of it.

The machine has a speed of 850 revolutions a minute; by means of two worms and wheels it turns a disc at $\frac{1}{1700}$th part of the speed, that is to say, at the rate of one revolution in two minutes. This disc is of double thickness, wood and copper. Two small rubbers bearing each against part of the disc communicate, one with the wires of the beacon, the other with the wires intended to balance the electric resistance of the lamp. The apparatus is so arranged that one of the rubbers is on the wood while the other is on the copper of the disc, and this very satisfactorily effects the intermittence of the beacon light. According to the calculations of M. Pouzolz the best proportion between the metallic and the insulating arcs of the disc is that which produces alternately 20 seconds of flash and 100 seconds of obscuration. But nothing is easier than to modify this proportion, even on the voyage; it is only necessary for that purpose to provide a series of discs having larger or smaller metallic facings.

The Brotherhood engine being set on a comparatively unstable foundation produced intense vibration, and noise so loud that it was impossible to hear in the engine-room; but this inconvenience will completely disappear in other cases where engines almost silent are employed.

The height of the light is 10 mètres above the water. The possible range of the light allowing for dip of the horizon is 10 knots (18,520 mètres) for an observer having his eye 6 mètres above the water.

For the purpose of illuminating the upper rigging while the lower sails are left in the dark, M. Pouzolz has had a truncated tin cone made, and placed on the movable lamp with its large opening upwards. Thus the 'Amérique' was seen at a great distance by vessels and signal stations when it suited the captain to let the electric light burn all night. This idea will render great service in anchorages.

What we have chiefly endeavoured to do in devising the arrangement of the 'Amérique,' is to avoid the more or less serious inconveniences which had been pointed out to us, and

which may be thus summed up: the electric light creates around it a whitish mist which fatigues the eye and interferes with observations; the constant electric light, by its great intensity, causes the disappearance of the regulation red and green lights, and this constitutes a real danger; near coasts, vessels may mistake the electric beacon for a lighthouse, and so go astray; finally, the apparatus is cumbrous, and its cost is too great in proportion to the services rendered by it.

The Gramme machines do not cost much, they are easily erected and worked, they run no risk of breaking down, and require only a very small space. The other objections are removed by the use of intermittent lights. M. Pouzolz concludes his report by declaring that "The light showing short flashes has never interfered with the view of an officer, or of the men at the binnacle, and the lustre of the red and green side-lights is in no degree diminished by the use of the forward beacon."

After experiments so conclusive, it seems that nothing should oppose the immediate adoption of the electric light on all vessels, for it is satisfactorily proved that the chief number of collisions result from the difficulty which captains experience in estimating the exact position of an approaching vessel, and in navigation the question of safety should take the lead of all others. Yet we do not think that the application will speedily become general; it is only gradually, after further trials, that the electric light will definitely take possession of the ocean. It is even to be desired that it should be so; for if we have succeeded in removing the inconveniences which have been pointed out to us. we hope certainly, in the arrangements which are to follow, to introduce important improvements. In our opinion the progress developes itself very slowly, but once consecrated by experience it remains protected from the recoils so common in the history of scientific and industrial innovations.

Attempts which succeed too quickly most frequently involve grave deceptions, and if we needed a proof of this assertion we should find it precisely in the first attempts made to apply electricity on ship-board.

Ten years ago M. Berlioz, then director of the Alliance

Company, fixed on board the 'Jerome Napoleon' an electric machine, with a reflector placed some mètres above the deck and intended to direct the light on the horizon. The success of this first application was much spoken of, and brought other orders to the same company.

Among the applications are those to the 'Saint-Laurent,' the 'Forfait,' the 'd'Estrées,' and more recently to the 'France,' belonging to the Maritime Carriers Company of Marseilles. With the exception of the last, about the result of which we are ignorant, none of these now exist, and at Saint-Nazaire is to be seen the totally rusted carcass of the electric apparatus from the 'Saint-Laurent.'

The 'Alliance' machines were, however, good, the reports of the captains on their use were favourable, only, unfortunately, sea damages did not become rarer.

The causes of the non-success arise especially from want of constancy in the trials, from stopping at the least inconvenience instead of seeking to overcome it. Changes in command were also prejudicial to the keeping of the apparatus on board.

There is also the economy to be taken into account, which here, as in all cases, must be an important consideration. It was hoped that from increasing safety the insurance companies would be led to reduce their premiums; this result not having been attained, electric lighting was regarded as an object of luxury. Hence the abandonment of a system instituted often at great expense.

For at least two years the introduction of the Gramme machine has been progressing on board the war-vessels of the French, Danish, Russian, English, and Spanish navies. The Transatlantic Company have re-continued the trials that were long ago interrupted, and it is to be hoped that these efforts will result in perfect realisation of the problem.

As far as the present time, no disappointment has been experienced, and increasing labour will doubtless improve the first arrangements and lead to still better means.

Amongst recent applications are those by Messrs. Sautter, Lemonnier, and Co., on the 'Livadia' and 'Pierre-le-Grand' of the Russian navy; the 'Richelieu' and the Suffren' of the

French navy; &c., &c.; and those by M. Dalmau upon the armoured Spanish vessels 'Rumancia' and 'Vitoria.'

The 'Livadia' is furnished with a Gramme machine giving about 500 Carcel burners, with which buildings may be clearly distinguished at a distance of 3000 mètres. This vessel has several times entered the ports of Odessa and Constantinople by night, and has been brought up alongside the quay as easily as by day.

The electric light was particularly useful one night at the commencement of winter, when—the continuous cold which had prevailed for several days increasing during the voyage—it was feared that the vessel might become ice-locked. It was necessary to seek refuge in a river where, at the entrance, the bar left only a buoyed channel of about twenty mètres. With the aid of the projector the channel was clearly distinguished, and the shelter of the river was quickly reached.

Aboard all these vessels the electric light has been utilised with great success as regards renewal of the carbons without waiting for the day.

The French naval authorities are about to install upon the 'Richelieu,' and will soon introduce on board the 'Suffren,' Gramme machines of 500 burners, directly actuated by a Brotherhood engine, and dispersing the light from lenticular projectors.

The new weapon of attack, the *torpedo*, carried or towed, puts the largest ironclads at the mercy of one of these rapid torpedo-boats. Experience has shown that however vigilant may be the watch kept on board a vessel of great depth above the water line, a nocturnal attack by a torpedo-launch is often successful. The launch, running at 15 or 18 knots, has attained its end before those attacked have a suspicion of its presence. This is not the case if the vessel attacked can explore the horizon in all directions for a distance of two or three miles. The enemy is discovered ten minutes before the attack, and this is sufficient time to prepare for defence, if even the attack is not prevented by the simple fact that it has been discovered.

The introductions on board ships are completed by a lenticular projector, constructed by Messrs. Sautter and Lemonnier. This

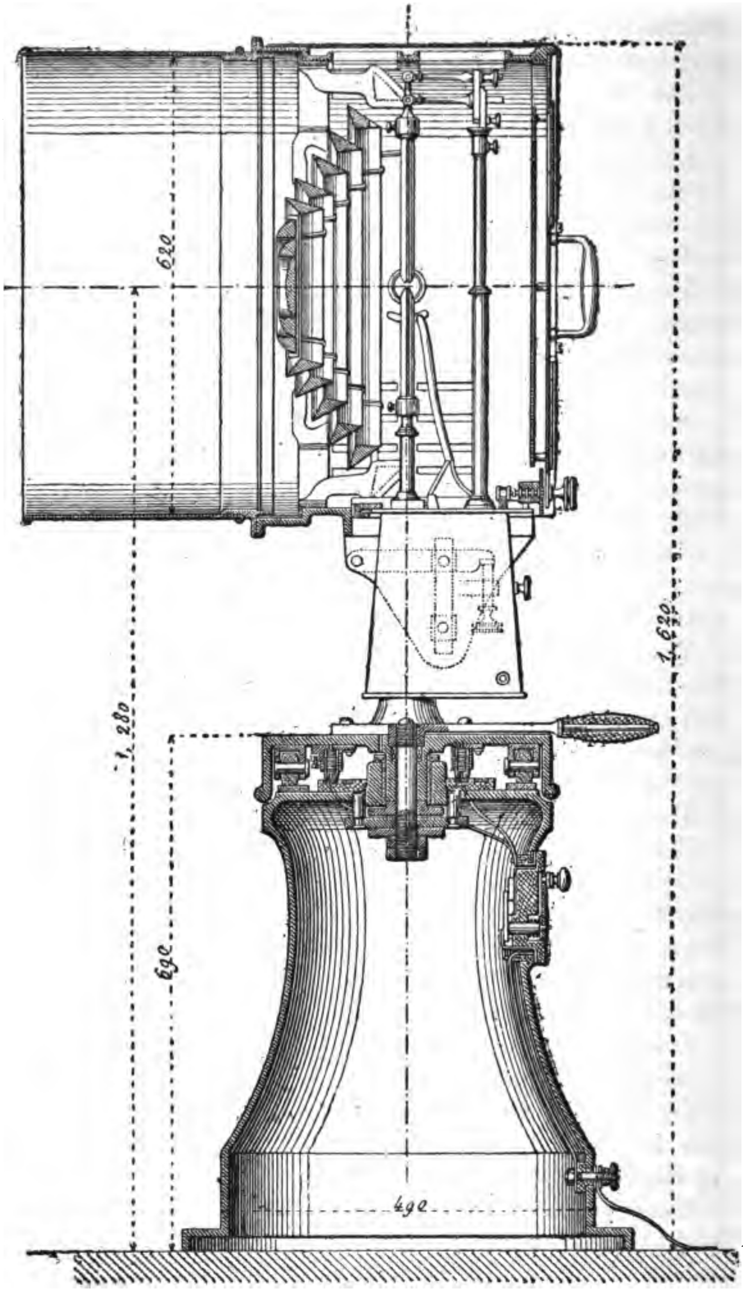


FIG. 43. SAUTTER AND LEMONNIER'S PROJECTOR.

projector, represented in Fig. 43, is intended to concentrate in a cylindrical sheaf the rays emitted by the lamp, and to give the operator the means of easily directing the light on any point. To this effect, the voltaic arc from a Serrin regulator is placed in the focus of a Fresnel lens of 0·60 mètre diameter, composed of three dioptric and six catadioptric elements. The lamp and the lens are carried by a cast-iron drum movable around its vertical axis, and turning on its horizontal axis, without altering the relative positions of the lamp and the lens. From this it results that whether at rest or in motion the luminous point remains at the optical focus, and the rays are projected into space in a direction following the optical axis of the lens.

The turning and oscillatory movements may be successive or simultaneous; they have for object the directing of the optical axis and, consequently, the luminous beam in all directions and at any inclination.

The operator has his position behind the projector, and effects his manœuvres by means of conveniently arranged handles.

Simply by the act of its introduction into the apparatus the lamp is put into the electric circuit, and is kept so whatever may be the motion imparted to the movable cylinder.

A small telescope placed on one of the bearings of the cylinder projects the image of the carbons upon a ground-glass screen, and allows of observation of the working of the lamp without the necessity of opening the cylinder. By means of a screw the position of the lamp can be altered when it is required to shift the luminous point beyond or from the focus to produce greater or less divergence of the beam. A second screw and clamp serves to maintain the beam in a given direction; the screw stopping the turning movement; the clamp preventing oscillatory movement.

For artillery purposes, a special arrangement admits, by means of tangent screws, of slowly displacing the luminous beam, and of exactly striking a previously given direction.

The complete apparatus is placed on a cast-iron socket, which can be affixed to the bridge on board ship, to the interior of a casemate in a fort, or on a movable carriage. By the aid of an interruptor the current can be suppressed at will without stopping the machine.

Application to Military Operations.

Several Governments having asked for very powerful Gramme machines for the defence of fortified places, the inventor, with Messrs. Sautter, Lemonnier, and Co., has designed a special

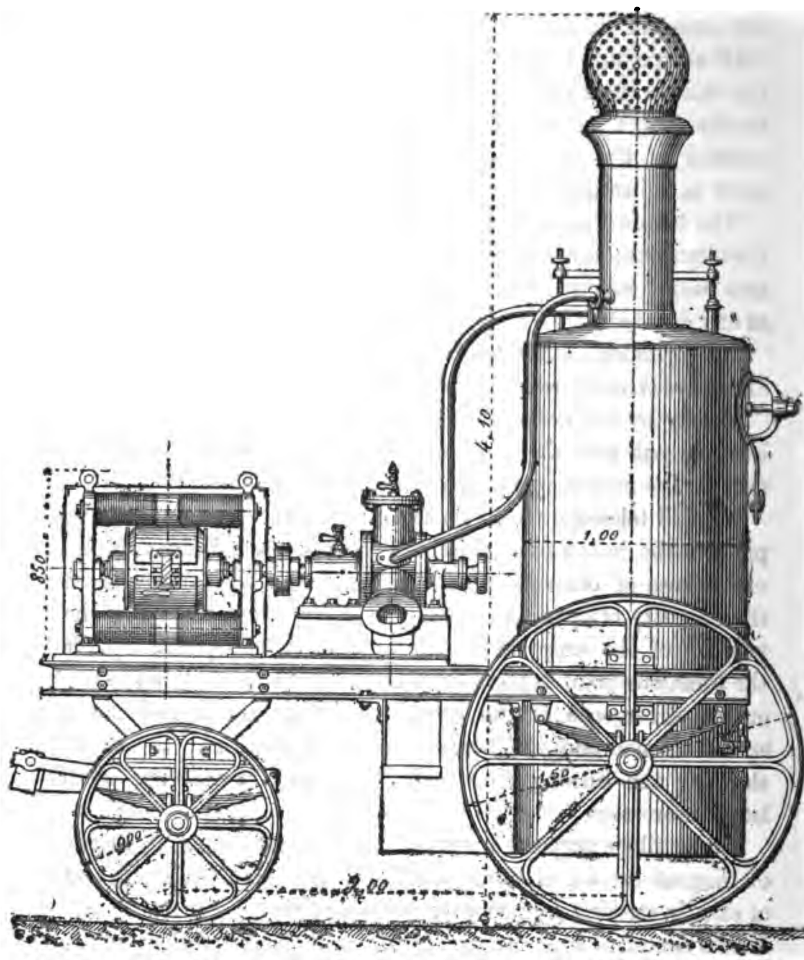


Fig. 44. Locomotive Gramme Machine.

machine, mounted on a trolly, and worked by a three-cylinder Brotherhood engine (Fig. 44).

The electro-magnets of the machine are flat and very large; the coil has two current receivers. A commutator mounted on the armatures admits of the coupling of the machine in tension or in quantity instantaneously.

The boiler is on Field's system with vertical tubes. The wheels are in double angle-iron. The whole apparatus possesses the qualities of lightness and power necessary to good service. It has been adopted in France, Russia, and Norway.

It resulted from trials made at Mont Valérien with a Gramme machine thus arranged and with a special projector, that an observer at the side of the apparatus could see objects 6000 mètres distant, and clearly distinguish details of construction at 5200 mètres.

The Gramme machine has a power of 2500 burners. The projector, the invention of M. Mangin, Lieutenant-Colonel of Engineers, instead of concentrating the light by simple refraction, concentrates it by refraction and reflection; this admits of obtaining perfect concentration of the rays and of doubling their penetration.

These trials, which were made in tolerably clear weather, with a rather transparent state of the atmosphere, have been repeated on dark nights with every success. By means of two cables the light has been produced at 1000 mètres from the apparatus without sensible diminution of intensity.

A great advantage that the Gramme machine possesses for military operations is the power, by simple manipulation of a commutator, of instantly giving twofold more powerful light, or reciprocally. This result is obtained by coupling the machine in tension or in quantity. In the first case it makes 600 revolutions, with an expenditure of 4 horse-power, and gives 1000 to 1200 burners' light; in the second case it makes 1200 revolutions, with an expenditure of 8 horse-power, and gives 2000 to 2500 burners' light. When the weather is clear the machine should be coupled in tension, then the expenditure of steam is small, and the carbon rods are slowly consumed. When the weather is foggy or very obscure, the machine is arranged in quantity, the expenditure of steam is increased, and the carbon rods are consumed more quickly. But in the second case the Gramme machine does not drag nor become heated.

With a Brotherhood motor, the change of power can be effected instantaneously.

For war signalling, M. Gramme has designed a machine of very small dimensions that can be turned by hand. This machine, worked by four men, produces a light equal to about 50 Carcel burners. It has flat electro-magnets, is mounted on a carriage, and receives motion from two handles acting on a double set of pinions. Its construction is rough, but well adapted to the part it is intended to fulfil. The French Government have acquired two of these machines for their army.

CHAPTER IX.

MOTIVE POWER ABSORBED BY THE GRAMME MACHINE.

Direct Experiments—M. Tresca's Report to the Academy of Sciences on the Force expended for Two Gramme Machines giving respectively 1850 and 302 Burners' Light—Report by M. Hagenbach, of Bâle, on a Machine of 80 Burners—Intensity of the Current—Electro-motive Force, Work absorbed —Messrs. Schneider and Heilmann's Report on the Lighting Power and Expense of Four Machines in the Ducommun Workshops at Mulhouse.

A GREAT number of experiments have been made in order to determine the amount of work absorbed by the Gramme machines, but none have given exact and concordant results, because of the difficulty of rigorously evaluating the light emitted by any focus, and of that not less of calculating the motor work at the moment of the photometric experiment.

Personally, we have frequently stated that with 3 H.P. we could obtain 600 burners' light, and that we should not be mistaken in assuming for a basis in calculations a half-kilogrammètre per burner.

M. Gramme has, during four years, much improved his machine from the point of view of expenditure of motor force; his workshop type, which produced in the beginning 100 burners with 3 H.P., now produces 450 burners with 2 H.P.

Among the more interesting trials made with the Gramme machines are those of: (1) M. Tresca, of the Institute; (2) M. Hagenbach, Professor at the University of Bâle; (3) M. Schneider, Professor of Physics at the Technical School at Mulhouse. These last were made with the help of M. Paul Heilmann, a manufacturer.

(1.) M. TRESCA'S EXPERIMENTS.

The trials made by M. Tresca were carried out in the workshops of Messrs. Sautter, Lemonnier, and Co., at Paris, on the 16th October, 1875, upon a machine of great power, and, on the 4th December of the same year, on a machine of medium power.

The former of these machines is represented at page 95. The following are the principal numerical data:

ELECTRO-MAGNET.

Diameter of the iron of one electro-magnet	0·070 mètre.
Length of the iron of one electro-magnet	0·404 „
Diameter of each electro-magnet filled with wire	0·132 „
Diameter of the wire	0·0033 „
Weight of copper wound on each electro-magnet	24·000 kilogrammes.

COIL.

Exterior diameter of the soft iron ring ..	0·175 mètre.
Interior „ „ ..	0·157 „
Width „ ..	0·119 „
Exterior diameter of the coil	0·230 „
Interior „	0·220 „
Total weight of wire wound	14·000 kilogrammètres.
Diameter of bundle of conductors	0·090 mètre.
„ wire	0·0026 „

CONDUCTING WIRE FROM THE MACHINE TO THE LAMP.

Diameter	0·0078 mètre.
Section	0·000047 sq. mètre.

MACHINE.

Total length, pulley included	0·800 mètre.
„ height	0·585 „
„ width	0·550 „

The second machine was constructed by M. Gramme, especially for use in lighting large uncovered spaces. It closely resembles the machine shown on page 100, and has the following dimensions:

ELECTRO-MAGNET.

Diameter of the soft iron of one of the electro-magnets	0·070 mètre.
Length	0·355 „
Diameter of each electro-magnet filled with wire	0·120 „
Diameter of the wire	0·0038 „
Weight of wire wound on each electro-magnet	14·320 kilogrammes.

COIL.

Exterior diameter of soft iron ring	..	0·168 mètre.
Interior „ „	..	0·123 „
Width „	..	0·101 „
Exterior diameter of the coil	..	0·203 „
Interior „	..	0·119 „
Diameter of the wire	..	0·002 „
Total weight of wire wound	..	4·650 kilogrammes.
Diameter of bundle of conductors ..	..	0·089 mètre.

CONDUCTING WIRE FROM MACHINE TO LAMP.

Diameter	..	0·026 mètre.
Section	..	0·000055 sq. mètre.

MACHINE.

Total length, pulley included ..	..	0·650 mètre.
„ height	..	0·506 „
„ width	..	0·410 „

In his Report to the Academy of Sciences, M. Tresca relates the difficulties he had experienced in setting up a dynamometer and in measuring the photometric indications:

"The high velocity," he says, "at which the Gramme machines are worked creates a difficulty in setting up a dynamometer that, as regards the diameter of the transmitting pulleys, does not make less than 250 revolutions per minute. However, the tracings furnished by the apparatus have been perfectly satisfactory, after some tentative experiments, inseparable from this kind of determination.

"The work expended has thus been measured with all requisite accuracy; but this is not the case as regards the luminous intensity. This intensity was measured by the aid of a direct-light photometer giving two contiguous zones, exclusively lighted, one by a Carcel lamp the other by the electric lamp. One of these zones appeared green relatively to the other, which had a rose tint; and among the several methods tried, that incontestably the best consisted in correcting the difference of these shades by the interposition of two slightly coloured glasses conversely.

"The standard Carcel lamp, consuming 42 grammes of oil per hour, was placed at a sufficient distance from the photometer, the

electric light being at 40 mètres in the first determination and at 20 mètres in the second.

"Despite the constancy of the electric current transmitted to the regulator, the light gave, from irregularity in the composition of the carbons, some variations which, for the greater part, are perceptible only in the photometric determinations; but there is, under these conditions, great difficulty in precisely determining this intensity, and in its definition with relation to the expenditure of work it necessitates.

"We have taken refuge from these inconveniences by multiplying the experiments, and by limiting them to a very short period. The standard lamp having been placed so as to balance, in the photometric field, the average light of the electric lamp, we kept the apparatus working during a certain time, and at the moment when we judged that there was equality of light, a signal was given to the observer of the dynamometer, who took a tracing for several seconds with care. Another observer recorded the corresponding number of revolutions of the dynamometer during one minute, and the taking of the dynamometric tracing was interrupted just when a signal transmitted from the observer at the photometer asked for a new tracing. In the following table will be found the data relative to these observations, which were completely successful.

TABLE OF EXPERIMENTS.

Large Machine.

		Mètres.
Ratio of distances at the photometer	.. .. ..	40·00 : 0·93
Ratio of intensities	.. ..	1850 : 1

Number of tracings.	Revolutions of the dynamometer per minute.	Mean ordinates of the diagram. Millimètres.	Work in kilogrammètres per second.
1	238	22·50	678·28
2	251	18·89	600·56
3	248	21·74	682·82
4	244	16·60	513·00
5	241	15·59	475·86
6	244	16·65	516·23
	Average 244		576·12 or 7·68 H.P.

$$\text{Work per 100 burners} = \frac{7 \cdot 68}{18 \cdot 50} = 0 \cdot 415 \text{ H.P.}$$

Work per burner and per second, 0·31 kilogrammètre.

Small Machine.

Ratio of distances at the photometer .. .. .. 20 : 1·15
Ratio of intensities .. .. 302·4 : 1

Number of tracings.	Revolutions of the dynamometer per minute.	Mean ordinates of the diagram. Millimètres.	Work in kilogrammètres per second.
1	234	7·11	201·72
2	238	6·66	200·79
3	244	7·42	229·41
	Average 239		210·65 or 2·81 H.P.

$$\text{Work per 100 burners} = \frac{2\cdot 81}{3\cdot 024} = 0\cdot 92 \text{ H.P.}$$

Work per second and per burner, 0·69 kilogrammètre.

"For the estimation of the number of revolutions of the axle of the magneto-electric machine, it was essential to be certain that there was no slipping of the belting. At different times, we compared simultaneously the velocities of the two axles by means of two revolution-indicators; we thus found for the former experiment a ratio of 15·6, whilst the calculated ratio was 5·26. The correction then became easy to make. The large machine was connected to a regulator on the Gramme system, fed with retort carbons having 0·012 mètre in the side, and the other to a Serrin regulator fed with carbons 0·009 mètre in the side."

Thus, with the intervention of the small machine, 1 kilogrammètre was transformed into 1½ burners' light, and with the aid of the large machine into more than three Carcel burners. These figures are even superior to those given as a basis at the commencement of this chapter; but they are the result of experiments made with the greatest care upon machines carefully verified by the inventor. In practice we ought evidently to look for a lower efficiency.

(2) M. Hagenbach's Experiments.

The report of M. Hagenbach on the Gramme machine is very interesting; it specially merits reproduction here, even if not entirely, and to avoid repetition upon the construction of the apparatus, at least in greater part.

"The Physico-chemical Institution, recently erected for the University of Bâle, has a large hall for popular lectures. This hall is so arranged that images from the solar microscope, magic lantern, spectroscope, &c., may easily be projected upon a large white screen, 6 mètres wide, and shown to an audience of four to five hundred. Either the electric light, solar light, or the Drummond light may be employed. As the production of the electric light by the aid of a Bunsen or Deleuil's battery is very disagreeable and costly, I thought of using an electro-dynamic machine for the production of the necessary light. This solution was more clearly pointed out by the fact that the town water-pipes give, in the physical laboratory, about 1½ H.P. for motor force.

"I employed a Gramme machine, not only to convince myself it would give the necessary light, but in order to study in detail the physical properties of these apparatus. As we may predict, with more or less certainty, that at no remote future magneto-electric machines will replace, for strong currents, galvanic batteries, the use of which is so inconvenient, the results of the researches I have undertaken for a particular end will undoubtedly present general interest.

"The machine upon which I have made my studies has electro-magnets 0·27 mètre in length. The interior moving coil, with ring of soft iron wire, consists of two parts which are introduced into the current one after the other; each of these halves possesses 48 partial coils. The whole current, that is to say, that which acts in the exterior circuit, circulates also around the electro-magnet.*

* It is here necessary to remark that the machine spoken of by M. Hagenbach was constructed in July, 1873, and that the putting of the electro-magnets into the exterior circuit had already been employed in several magneto-electric machines by M. Gramme.

"By measuring the galvanic resistance by the Wheatstone bridge, I obtained—

		Siemens' Units.
For the electro-magnet	.. ..	1·26
„ interior bobbin (the two parts)	.. ..	0·62
Total	..	1·88

"The electro-motive force of a Gramme machine is, as may be easily understood, very variable. It depends upon the velocity with which the interior coil revolves, and upon the intensity of the current circulating in the electro-magnet; this latter depends in its turn upon the resistance of the exterior circuit.

"In order to execute the measurements of current-intensity necessary to calculate the electro-motive force, I shunted a feeble portion of the current through a reflecting galvanometer. A previous experiment had shown how much detonating gas the principal current furnished per minute for a deflection of one degree on the galvanometer. I expressed the current intensities by the volume of detonating gas given off in a minute, reducing it to 0 degree and 0·760 mètre pressure. A cubic centimètre of gas corresponds to 0·0009926 chemical unit of 0·009 gramme of water decomposed per second. From the value of the intensity of the current and the resistance, one was then able to deduce that of the electro-motive force; this I express in the zinc-carbon elements of Deleuil, such as are ordinarily employed for the production of the electric light; I have valued the electro-motive force of one of these Deleuil's elements at 0·0192 chemical unit, or at 1·6 Daniell's.

"The number of revolutions of the machine was estimated by means of a Deschien's velocimeter.

"To determine beforehand in what measure the intensity of the current and the electro-motive force depend upon the speed of rotation and the exterior resistance, I made the following experiments:—

"I worked the machine at different speeds by intercalating different exterior resistances, and measured the intensity of the current, of which I deduced the electro-motive force. In this manner I obtained the following results:

"I. The circuit of the machine was closed by means of a short, thick wire, the resistance of which might be neglected;

we had then no exterior resistance, and a total resistance equal to 1·88 Siemens' units.

Number of revolutions per minute.	Intensity of the current in centimètres of gas per minute.	Electro-motive force expressed in Deleuil elements.
285	46·0	4·5
386	78·0	7·6
421	86·0	8·4
495	97·1	9·4
537	112·6	10·9
584	123·8	12·0
744	150·7	14·6
817	160·3	15·6
879	166·6	16·2
930	172·5	16·8
978	177·7	17·3
1045	183·0	17·8
1082	186·8	18·2

"II. The circuit of the machine was closed by means of a longer copper wire coated with gutta-percha, and representing a resistance of 0·5 Siemens' units, which gave a total resistance of 2·38 Siemens' units.

Number of revolutions per minute.	Intensity of the current in centimètres of gas per minute.	Electro-motive force expressed in Deleuil elements.
253	9·3	1·1
365	44·4	5·5
450	69·0	8·5
597	96·8	11·6
818	129·8	16·0
906	140·7	17·3
981	147·9	18·2
1109	161·7	19·9
1175	166·4	20·5
1283	176·3	21·7

"III. A still longer wire, representing two Siemens' units, was introduced into the circuit, which gave a total resistance of 3·88 units.

Number of revolutions per minute.	Intensity of the current in centimètres of gas per minute.	Electro-motive force expressed in Deleuil elements.
539	41·0	8·2
707	70·0	14·0
905	91·2	18·3
1178	110·5	22·2
1416	129·8	26·0
1584	142·1	28·5

"If we represent these results graphically, by taking the number of revolutions as abscissæ and the intensities of the current as ordinates, we obtain curves which recede but little from a straight line, and which present a slight concavity below the line. The intensity of the current increases then nearly in proportion with the speed of rotation. By still further augmenting the speed by means of a stronger motor, we should have been well able to carry the intensity of the current still higher, had it not been that above 2000 revolutions a minute the machine becomes too strongly heated.

"If one deduces from the above tables, by interpolation, the electro-motive forces for the same number of revolutions, or the electro-motive forces for the same intensity of current but for different numbers of revolutions, we easily discern that, for feeble intensities of current, the electro-motive force increases with the intensity of the current. But when this latter becomes great enough to develope 80 cubic centimètres per minute, the electro-motive force does not augment sensibly with the intensity of the current, because, without doubt, the feeble current suffices to produce complete magnetisation. Moreover, one finds out that, for a constant intensity of current, the electro-motive force is perceptibly proportional to the number of revolutions; this should be so according to the law of induction.

"For the production of the electric light, I employed a Serrin regulator. I measured the intensity of the light with the aid of a Bunsen photometer, taking as the light unit the normal paraffin candle of 0·0214 mètre diameter, giving a flame of 0·0413 mètre height. For measuring the resistance produced by the introduction of the electric light, I measured the number of revolutions and the intensity of the current; then I took away the electric regulator and introduced higher and higher resistances, until I returned to the number of revolutions and to the intensity of current that I had at first. I obtained in this manner, for the resistance caused by the electric lamp, 4·75 Siemens' units; which gave, for the total resistance after the production of the electric light, 6·63 Siemens' units.

"The measurements made of the luminous intensity and of

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the corresponding intensity of current have led me by calculation and interpolation to the following results:

Number of revolutions per minute.	Intensity of light in normal candles.	Intensity of current in cubic centimètres of gas per minute.	Electro-motive force in Deleuil elements.
1700	506	119	40·8
1800	567	126	43·2
1900	628	133	45·6
2000	689	140	48·0

"Some experiments made with Prony's dynamometer have shown me that, for the production of the light at 1800 revolutions per minute, the power expended is about 90 kilogrammètres, that is to say, more than one horse-power.

"Now 567 normal candles are nearly equivalent to 80 Carcel burners; 1·1 kilogrammètre is therefore necessary for the production of one Carcel burner with our machine.

"The galvanic resistance of one of my Deleuil elements is equal to 0·083 Siemens' units; 72 elements in series are therefore necessary for producing the same light as the Gramme machine produces at 1700 revolutions per minute, and 86 elements for producing the same light as the machine produces at 2000 revolutions; this clearly shows that the employment of the Gramme machine, for the production of the electric light, as compared with the battery has the advantage not only of greater convenience but also of great economy.

"The Gramme machine that I have employed amply suffices for the projection to an enlarged scale of photographs, microscopic preparations, and spectra."

(3) Experiments of Messrs. Schneider and Heilmann.

The experiments of Messrs. Schneider and Heilmann are remarkable in that they were made with machines that had already worked for a year, and in the same place where they were erected. At the sitting held in 1876 by the Société Industrielle de Mulhouse, on the occasion of its fiftieth anniversary, the report was read, and the experimentalists paid a tribute of profound homage to the marvellous invention of M. Gramme.

Though it be somewhat irrelevant to the subject of this chapter, we cannot resist the desire to quote the first lines of the introduction of the report, they express well the thoughts of all men of science and manufacturers that know of the new magneto-electric machine with which we are dealing.

"Gentlemen:—You have doubtless asked yourselves what motives have guided us in the choice of the subject that we wish to bring before you to-day.

"Your committee on mechanism, Gentlemen, desire at this great and solemn festival to render homage to one of the most beautiful discoveries of our era; the easy and practical mechanical production of electricity.

"You know all the multitudinous effects of this curious natural power.

"The word electricity means: heat, light, chemical actions, molecular movement, magnetic effects, transmission of power to great distances, and many other secrets still to be wrested from nature.

"If these effects are marvellous, you know, also, how much difficulty has hitherto been experienced in obtaining them when they were sought from electric currents of great intensity.

"Now the difficulty is surmounted; thanks to the invention of Gramme, the horizon opens out widely before us, and puts at our disposal the easy and practical employment of electric currents.

"Honour to him who, the first, has found a practical solution of this problem so long unsolved.

"Gentlemen, let us go back fifty years, and let us think of the founders of this Society to whose memory we to day render homage.

"What would our fathers have said? what would these first champions of Alsatian industry have said, if they had seen opened for them this new industrial era, which puts electricity at our disposal?

"Our predecessors have bequeathed to us: the oil-lamp, the gas-light. In this fiftieth anniversary of the foundation of our Society, we will bequeath to our successors one of the numerous applications of our new industrial power: the electric light."

The part of the report special to the determination of the luminous power was made by M. Schneider. The following are the most striking points:

"All persons familiar with photometric measurements know that it is impossible to compare with exactness the intensities of two luminous sources differing in colour. The eye in comparing two illuminated surfaces is not capable of distinguishing the difference due to inequality of intensity from the difference of colour.

"Such was nevertheless the problem that we have had to solve. It is not necessary, in fact, to have recourse to the examination of the spectra furnished by a Carcel lamp on one hand and an electric regulator on the other to prove the great difference in the constitution of these two luminous sources. A simple glance cast on the field of a Foucault's photometer exposed to the rays of these two lights, shows that the first emits a rosy yellow light, beside which the colour of the second appears as a violet green.

"M. Tresca, who has recently been occupied with the determination of the work expended by two Gramme machines of great illuminating power, has succeeded in overcoming the difficulty in question by correcting the difference in tint by the interposition of two glasses slightly coloured in inverse manner. But besides the want of a proper scale of glasses slightly coloured, we hesitated to admit that the quantities of light absorbed by the coloured media interposed should be entirely neglected, or should be considered proportional to the intensities of the sources which are subjected to these losses of light.

"We, therefore, confined ourselves to the direct comparison of the intensities of the two luminous sources in question. The results that we have obtained should be considered only as approximations rude enough in respect of scientific method, but nevertheless sufficient for practical purposes.

"Our determinations present so little the character of exact experiments, in so far that we had to operate in the foundry itself, the ceiling and walls of which could reflect on the photometer a certain quantity of diffused light, notwithstanding the precaution we took to preserve this instrument as much as

possible from every disturbing influence by means of a hood of thick black calico.

"We employed for our experiments the excellent photometric apparatus of Messrs. Dumas and Regnault, of which we need not give a detailed description. This apparatus is furnished with a Foucault photometer, of which we so far prolonged the intervening partition that each half of the glass plate was exclusively lighted by one of the two luminous sources under comparison.

"Following the example of M. Tresca, we took as unit the light emitted by a Carcel lamp burning 40 grammes of purified colza oil per hour. The lamp, regulated approximately for this consumption, was placed upon the balance which formed part of the photometric apparatus at a constant distance of 1 mètre from the glass plate. The electric regulator was placed upon a movable carriage of suitable height, capable of being easily moved along a divided rule of about 12 mètres in length.

"To ascertain the consumption of the Carcel lamp during the different phases of the experiments, we began by balancing the lamp already lighted; then, overloading slightly the opposing scale, we noted the precise instant when the fall of the hammer on the bell indicated the commencement of the experiments. Raising then the alarm hammer, we charged the lamp with additional weights, varying according to the intended duration of the trial, and carefully noted the exact time corresponding to each fresh fall of the hammer upon the bell.

"The Bunsen photometer being less sensitive than others to the disturbing influence arising from a difference of colour in the luminous sources, we thought it useful to compare the indications of this apparatus with those of the Foucault photometer. In order that we might effect the determinations with sufficient rapidity, we adopted an arrangement similar to that of M. Burel, of Rouen. Our photometer consisted of a rule, divided in centimètres, interposed between the Carcel lamp and the electric regulator, upon which a small vertical paper screen, carrying in its centre an impression similar to that of the stamped paper, slides. In this manner each side of the scale is lighted exclusively by the source of light placed opposite to the side to be examined. For taking a measurement, the operator, observing

in all experiments the same side of the scale, displaces slowly this latter until the complete disappearance of the central spot, and then notices upon the divided scale the distance of the screen from each source of light.

"However easy of demonstration it may be that a similar mode of operation only is known to furnish, with an absolute accuracy,* the proportion of the luminous intensities to be compared,

* In fact, the light which strikes on each side of the screen becomes décomposed into three parts, of which one is reflected, the other transmitted, and the third absorbed.

Let us denote for the non-translucid side of the screen:

by a the quantity of reflected light,
by b the quantity of transmitted light,
by c the quantity of absorbed light,

and let $\alpha\ \beta\ \gamma$ be the quantities of light reflected, transmitted, and absorbed by the translucid side of the screen.

In representing by 1 the intensity of the incidental light, we shall have the relations:

$$a + b + c = 1,$$
$$\alpha + \beta + \gamma = 1.$$

If the left-hand side of the screen is lighted by a source of intensity i, and the right-hand side by a source of intensity i', the quantity of light J that the non-translucid part of the screen will send to the eye of the observer, invariably placed on the same side of the screen (to the left, for example), will be represented by:

$$J = i\,a + i'\,b.$$

In the same way the translucid part of the screen will send to the same observer a quantity of light J′ given by the relation:

$$J' = i\,\alpha + i\,\beta.$$

This admitted, if no part of the screen absorbs the least portion of the incidental light (that is to say, if we have $c = o$ and $\gamma = o$), or better if the translucid part of the screen has absorbed as much as the non-translucid part (that is to say, if we have $c = \gamma$), we shall have:

$$a + b = \alpha + \beta;$$

and consequently, by supposing $i = i'$, we shall have $J = J'$, that is to say, the translucid spot and the groundwork appear to be equally lighted, and the spot will disappear.

But this case never happens in reality. In fact as the translucid part absorbs less light than the non-translucid part, $\gamma < c$, and consequently

$$\alpha + \beta > a + b.$$

But, when the screen is placed at an equal distance from two sources of equal intensity, $i = i'$ and

$$J = i\,(a + b),$$
$$J' = i\,(\alpha + \beta);$$

whence it results that

$$J < J',$$

we have not hesitated to inscribe as the measures obtained the numbers furnished by the Foucault photometer.

"The results of all the photometric experiments are recorded in the fourth column of the table. They often present a remarkable concordance, but also notable divergences. These differences should be attributed, not only to the imperfections inherent to all the usual photometric methods, but also to the variations experienced by the electric light in consequence of the irregularity of the composition of the carbons. These fluctuations of intensity which, according to a second series of photometric determinations effected on the 25th of last March, do not rise above 10 per cent., do not escape the eye looking into the field of the Foucault photometer. They are sometimes perceptible to the ordinary view of a practised observer.

"The great discordance that the indications of the two photometers present in several experiments, belongs incontestably to the diffused light that the ceiling and the nearest wall may have thrown upon the slab of the photometer exposed to the rays of the Carcel lamp. In the first of these experiments, the voltaic arc was uncovered, and in the second it was enveloped by a frosted globe opened widely at its upper and lower extremities. The light of the Carcel lamp was thus reinforced by a certain amount of diffused light, the luminous intensity of the regulator used for measurement being forcibly lessened in the same proportion.

"It results finally from these experiments that the intensity of the electric light, unenfeebled by a globe of frosted glass, sensibly exceeds 100 Carcel burners for the Gramme machines working under the conditions indicated.

"As moreover the least intensities observed with the employ-

that is to say, the spot will disappear only at the precise instant when the screen is equally lighted on both sides. It will appear brilliant upon a groundwork relatively dark, and to make it disappear it would be necessary to draw the screen a little towards the eye of the observer.

It also results from the preceding, that the spot can never disappear simultaneously on both sides of the screen.

To obtain with this photometer the exact proportion of the intensities of two luminous sources, it is, then, absolutely indispensable to have recourse to the ingenious arrangement conceived by M. Bunsen; but this is not the place to give a description of it.

ment of a diffusing globe are equivalent to 80 Carcel burners, one may conclude that the glass globes absorb about 25 per cent. of the light emitted by the voltaic arc in a determinate direction."

At the same time that M. Schneider made the photometric experiments in the new foundry of the Ducommun ironworks, M. Heilmann studied, by dynamometric experiments, the motive power absorbed by the Gramme machines. To this end he took a series of curves, with the aid of a Watt's indicator, upon a Sulzer machine working the four apparatus.

This method, essentially different from that employed by Messrs. Tresca and Hagenbach, is certainly the most practical when one has no recording dynamometer at his disposal. The results which it gives are sufficiently exact, especially if one takes care, as M. Heilmann has done, to set off a great number of curves.

But let us quote the report:

"We have in the first place sought to make the steam-engine expend a constant motive power, of which we have determined the value by diagrams. This constant established, we have made the motor work over and above the constant expenditure one or several Gramme machines, according to the programme of the photometric experiments; and it was then easy for us to estimate by difference the motive power absorbed above that for each of the experiments.

"The photometric and dynamometric experiments were not made in the same place; we put ourselves in communication with each other by such a signal that the experiments were made simultaneously in each case.

"In the small table we have summarised the results of our experiments, and placed each indicated number of the dynamometric experiments opposite to the corresponding figure of the photometric experiments.

"Our experiments lasted 2 hours 48 minutes, and during this time 94 diagrams were taken upon the cylinder of the steam-engine.

"The Serrin regulators were supplied with carbons close-grained, compact, and hard.

"These carbons resisted the action of the electric current

better than the soft carbons; but, in comparison, they gave a less brilliant light, presented more resistance to the electric current, and consequently expended more motive power; the soft carbons gave a bright light, expended less motive power, but they are subject to splitting and throwing off splinters of carbon.

"Our aim was to carry on the use of the hard carbons, which presented a greater guarantee of regular working.

"These experiments have led us to the following results:

"Neglecting initial or starting force, and only considering as the expenditure the motive power absorbed in average and current working, we have proved that:

"The four Gramme light machines, of the emissive light power of, roughly, 400 Carcel burners, which worked in the Ducommun workshops, expended about, in current working:

	Kilogrammètres.	Horse-power.
The four machines together, starting speed not included	539·5	7·194
Starting speed	62·2	0·829
The four machines together, with their starting speed	601·7	8·023

"For each Gramme light machine taken individually at arranged intervals, in a duration of two hours, we have found the following averages, starting speed not counted:

Regulator	2,	Gramme machine	B, 1·921	horse-power.
,,	2,	,,	A, 1·849	,,
,,	2,	,,	C, 1·833	,,
,,	2,	,,	D, 1·360	,,
		All together ..	6·963	horse-power.

"This result for the four machines has been obtained without starting speed being counted, that is to say, a little nearer to that which is indicated above.

Regulator	1,	Gramme machine	B, 1·980	horse-power.
,,	2,	,,	B, 1·921	,,
,,	3,	,,	B, 1·710	,,
,,	4,	,,	B, 2·001	,,
		Total for four experiments	7·612	horse-power.

"This result gives an average of 1·903 horse-power, starting speed not counted; this is what we have found above for machine B.

"It is necessary to distinguish the motive power absorbed by the Gramme machine for setting it to work, from the motive power absorbed in current working.

"During the first twenty-five or thirty seconds which follow the setting to work, the Gramme machine absorbs as much as 67 per cent. above its normal expenditure. This, already discovered by M. Tresca, arises not only from the resistance opposed by the inertia of the matter of a body which is suddenly put in motion, but it arises moreover from the power necessary for establishing the electric currents.

"If the carbons have not been previously cut, the time during which, from the setting to work, the increased expenditure of motive power would take place would be a little longer.

"From the preceding considerations it is to be seen that, in the case of an introduction of Gramme light machines, it is necessary in calculating the motive power to be used to admit that for a short time the steam-engine should be capable of giving an increase of nearly 75 per cent. upon the motive power absorbed on the average in current working; or it would occur during this short time that the transmission of movement was slightly diminished from its normal speed.

"The results we are about to indicate relate to the use of hard carbons of square section of 0·007 mètre in the side; they burnt at the rate of 0·120 to 0·125 mètre per regulator and per hour.

"As we have before said, in the case of using soft carbons, such as are actually obtained, the motive power absorbed will be diminished; but against this the intensity of the light will be less regular.

"The following table summarises the principal experiments of Messrs. Schneider and Heilmann:

Description of Machines.	Number of Revolutions of Machines.	Work absorbed in Horse-power.	Intensity of Light by Bunsen Photometer in Burners.	Observations upon the Regulators.
Machine B	816	1·921	95·6	Regulator with frosted globe.
Machine B	816	1·921	122·2	Regulator without globe.
Machine B	804	1·980	86·8	Regulator with frosted globe.
Machine A	810	1·849	85·3	Regulator with frosted globe.
Machine C	763	1·833	103·2	Regulator with frosted globe.
Machine D	883	1·360	68·7	Regulator with frosted globe.

The last experiment gave 81 burners with the Foucault photometer, which corresponds to more than 100 burners without the globe, and the expenditure of 1·36 horse-power did not vary. This is very nearly 1 kilogrammètre per Carcel burner.

By comparing this last valuation with that we have before given (page 101), it will be seen how much M. Gramme has improved his machines since the introduction at Mulhouse.

CHAPTER X.

COST OF ELECTRIC LIGHTING.

Cost of Lighting by means of a Bunsen Battery—Evaluation by M. Becquerel—Tabulated Expenses by Messrs. Lacassagne and Theirs—Cost of Lighting by means of the "Alliance" Machine—Cost of Lighting by means of the Gramme Machine—Tabulated Comparison of the Cost of various Lights—M. Heilmann's Calculations—Comparative Estimate for the Introduction of Gas and Electricity.

Although the use of the battery is disappearing since the invention of M. Gramme, it will not be profitless to examine what was the expenditure for this method of producing light.

Upon this subject accurate data are to be found in a report presented twenty years ago to the Société d'Encouragement by M. Edouard Becquerel.

The important point to be determined in these researches on the battery, is the average consumption of zinc, sulphuric acid, and nitric acid necessary to obtain a constant light for several hours. Now, experience proves that the luminous intensity decreases very rapidly when the current itself diminishes much less quickly. This difference of decrement between the current and its effects is besides irregular, and this makes it impossible to exactly determine the law for the consumption of the substances necessary to the production of a given light.

But, despite this, limits may be indicated between which the total expense is included when batteries are used the dimensions of which are known.

Thus, with 60 Bunsen elements of 0·20 mètre height, in work during three hours, there was obtained, at the commencement, 75 Carcel burners at a cost of 2·85 francs per hour, and at the end of this time 30 Carcel burners at a cost of 2·15 francs per hour. The expenditure of zinc was calculated from the intensity of the current measured on a sine galvanometer

introduced into the circuit, and proportioned to the action which would be produced in a voltameter containing sulphate of copper by an electric current of the same intensity; that of the sulphuric and nitric acids was calculated from their equivalents. It is certain that the actual expenditure is much greater than that indicated by the theory of electro-chemical decomposition; besides, there is some loss of mercury, the nitric acid is too much weakened to serve for another experiment, &c., so that M. Becquerel estimates the cost for 60 elements to be at least 3 francs per hour.

This result has besides been confirmed by direct trials made at Lyons in 1857, for the lighting of the Rue Impériale (now called the Rue de Lyon). The lamp, Lacassagne and Thiers' system, was fed by 60 Bunsen elements. It was in operation for 100 hours.

Name of Substance.	Consumption in 101 hours.	Cost.	Total Cost.	Cost per Hour.	Observations: Actual Cost.
			francs.	francs.	
Zinc	72·00 kilos.	104 francs per 100 kilos.	74·95	0·75	80 francs per 100 kilos.
Sulphuric Acid	154·00 „	24 „ „	36·95	0·37	12 „ „
Nitric	247·00 „	70 „ „	173·25	1·73	56 „ „
Mercury	9·50 „	550 „ „	49·75	0·50	650 „ „
Purified Carbon	6·61 mètres	3 „ per mètre.	19·85	0·20	2·5 „ per mètre.
		Total	354·75	3·55	

The preceding table gives exactly the substances consumed, the price paid by the experimenters, the cost per hour of lighting, and the cost of the substances.

In applying the actual prices of materials to the quantities consumed the cost of 3 francs per hour is arrived at, as in M. Becquerel's experiments.

This cost is certainly subject to reduction if the light is to be employed in a workshop permanently; the mercury could be recovered, the nitric acid economised, the sub-products utilised, &c. However, as on the other hand the cost of 3 francs does not include interest upon capital for first establishment, nor labour, nor general expenses, and as the introduction of electric lighting, on however large a scale, will never result in sufficient consumption of chemical products to allow of any great profit, it may

be admitted that the cost of 3 francs per hour, for an average light of 50 Carcel burners, is a minimum in practice.

In the same report M. Becquerel makes the following statement, which we give, as it fills a void in the preceding chapter, and will serve to pass from lighting by the battery to lighting by magneto-electric machines:

"It is interesting to compare these figures with those we should obtain if we evaluate the force communicated to an "Alliance" magneto-electric required to furnish an electric current capable of maintaining a constant voltaic arc similar to that which has served in trials with the battery. If we compare these results with those obtained in 1856, with the machine employed at the Conservatoire des Arts et Metiers, we find that it would be necessary to communicate a force of 2¼ horse-power to that machine in order to give an electric current capable of maintaining constant a luminous arc having a light intensity of 50 Carcel burners."

M. Le Roux, in the meetings already mentioned, gave complete items of expenditure occasioned by the use of the "Alliance" machine in industrial lighting; only, we would remark that he supposes 360 days' use per year, whilst in the majority of workshops there would be night work on only 100 days per annum, which much increases the actual cost per hour of lighting.

The following is M. Le Roux's estimate for a light of 125 Carcel burners:—

1. The most unfavourable case, where the motor which gives motion to the magneto-electric machines has no other use, and requires a special stoker:

For a service of 10 hours per day:

	Francs.
Interest at 10 per cent. upon 12,000 francs for first introduction, per day	3·35
Coal, 100 kilogrammes at 40 francs the *tonne*	4·00
Wages of stoker	5·00
Carbon rods	3·60
Oil, &c.	1·30
Cost per day	17·25

For a service of 5 hours per day:

	Francs.
Interest at 10 per cent. upon 12,000 francs for first introduction	3·35
Coal, 50 kilogrammes at 40 francs	2·00
Stoker	5·00
Carbon rods	1·80
Oils, &c.	0·70
Cost per day	12·85

2. The most favourable case; the motor power being taken from a powerful machine used for other purposes.

For a service of 10 hours per day:

	Francs.
Interest at 10 per cent. on 9000 francs	2·50
Coal, 40 kilogrammes at 40 francs	1·60
Carbon rods	3·60
Oil, &c.	0·70
Cost per day	8·40

For a service of 5 hours per day:

	Francs.
Interest on 9000 francs at 10 per cent.	2·50
Coal, 20 kilogrammes at 40 francs	0·80
Carbon rods	1·80
Oil, &c.	0·40
Cost per day	5·50

Admitting 100 days at 5 hours, or 500 hours' lighting per year, the preceding figures for daily cost become, in the unfavourable case, 21·50 francs for 5 hours, or 4·30 francs per hour; and, in the favourable case, 15 francs for 5 hours, or 3 francs per hour. This gives 0·034 franc per burner per hour in the first case, and 0·024 in the second. These costs correspond very nearly to that occasioned by gas-lighting in the municipality of Paris.

Let us now examine several costs of lighting obtained with the Gramme machine. The large number of industrial applications made with this machine will allow us to give most complete and precise data on this subject.

Principally, and with very rare exceptions, M. Gramme has advised the use of his machine only where there are large spaces

to be lighted, and where there is a sufficiently powerful motor to prevent the addition of one or more machines interfering with the regular progress of the work. In 100 introductions, 90 have been made upon these data. Upon this kind of application we then commence our calculations.

A Gramme machine of 150 burners, mounted on a base, costs 1600 francs; a Serrin regulator, 450 francs; the cost of cable for transmission varies, according to the length, from 1 to 2 francs per mètre. With cost of packing, transport, and mounting, a complete apparatus ready for use costs at a maximum (in France and the frontier countries) 2500 francs, inclusive.

The retort-carbons for the regulator cost 2 francs the mètre; their consumption is 0·08 mètre per hour, waste included.

With 500 hours night work per year and four apparatus in the same establishment, the annual expenses, if a steam motor is employed, are:

	Francs.
4000 kilogrammes of coal at 35 francs per tonne	140
160 mètres of retort carbon	320
Maintenance of the machines, 0·50 franc per hour	250
Interest upon 10,000 at 10 per cent. per annum	1100
Total	1810

If hydraulic power is employed these expenses are reduced to 1570 francs; thus, the light produced by four foci of 150 burners each, during 500 hours, costs 1810 francs when the Gramme machines are worked by a steam motor, and 1570 francs when these machines are actuated by a hydraulic wheel.

For a single focus, it is necessary to take the maintenance at 0·30 franc per hour, which slightly increases the cost proportionally. For eight foci, on the contrary, the cost of maintenance will not exceed 0·75 franc, and the cost is proportionally reduced.

When work is carried on for the whole night all the year round, as at M. Ménier's, at Noisiel, the cost for 4000 hours of night work, per focus, with a hydraulic motor, consists of:

	Francs.
320 mètres of retort carbon	640
Annual maintenance of the apparatus at a maximum ..	200
Annual interest	250
Total	1090

With the use of a steam motor this figure will be increased by 280 francs, the cost of eight tonnes of coals at 35 francs per tonne; it will then be 1370 francs.

The cost of the unit of light per hour produced by Gramme machines (150 burner type), calculated according to what precedes, is as follows:

	Francs.
For 500 hours per year with a steam motor	0·0070
For 500 hours per year with hydraulic power ..	0·0066
For 4000 hours per year with a steam motor ..	0·0023
For 4000 hours per year with hydraulic power ..	0·0018

With the new Gramme machines (type 1877) and Gaudoin carbons, the price of unit of light per hour is reduced 40 per cent.; it then becomes:

	Francs.
For 500 hours per year with a steam motor	0·0042
For 500 hours per year with hydraulic power ..	0·0040
For 4000 hours per year with a steam motor ..	0·0016
For 4000 hours per year with hydraulic power ..	0·0011

These figures are from practical results; none of the statements are too favourable; on the contrary, in many applications it is known that the expense per Carcel burner is less than we have stated.

It should be clearly understood in what precedes that these introductions were made where a motor existed, and we will now see what will be the cost when the material for lighting includes, besides electrical apparatus, a special motor.

The table following gives the cost of the unit of light produced by several substances and by magneto-electric machines. As gas is most generally taken for comparison, we have varied the purchasing price at from 0·15 franc to 0·30 franc per cubic mètre.

In order to calculate the cost of gas-lighting we have added to the current expenses a premium of four francs per year and per burner to cover interest and maintenance of apparatus.

The table shows that for the same intensity, the Gramme machine, in the most unfavourable case, yields a light

75 times	less	expensive than	that from	wax candles.
55	,,	,,	,,	stearine candles.
16	,,	,,	,,	colza oil.
11	,,	,,	,,	gas at 0·30 franc } per cubic mètre.
6½	,,	,,	,,	gas at 0·15 franc } per cubic mètre.

Under the most favourable conditions, this light is

300 times less expensive than that from				wax candles.
220	,,	,,	,,	stearine candles.
63	,,	,,	,,	colza oil.
40	,,	,,	,,	gas at 0·30 franc per cubic mètre.
22	,,	,,	,,	gas at 0·15 franc per cubic mètre.

TABULATED COMPARISON OF COST OF VARIOUS LIGHTS.

Description.	Quantity burnt per hour.	Cost per burner per hour.	Cost for 4000 burners per hour.	Observations.
	grammes.	francs.	francs.	
Purified Colza Oil ..	42	0·07	28·00	Price per kilog. 1·70 francs.
Neutral Allaire Oil	39	0·06	24·00	,, ,, 1·55 ,,
Shale Oil	36	0·0468	18·72	,, ,, 1·30 ,,
Petroleum Oil	30	0·054	21·60	,, ,, 1·80 ,,
Tallow Candle.. ..	83	0·141	56·40	,, ,, 1·70 ,,
Wax Candle	66	0·33	132·00	,, ,, 5·0 ,,
Stearine Candle ..	82	0·246	98·40	,, ,, 3·0 ,,
Voltaic Battery ..	,,	0·06	24·00	
"Alliance" Machine	,,	0·024	9·00	For 500 hours per year.
"Alliance" Machine	,,	0·007	2·80	For 4000 hours per year.
	litres.			
Oil Gas	140	0·029	11·60	At 0·15 franc per cubic mètre: 500 hours per yard.
Oil Gas	,,	0·025	10·00	At 0·15 franc per cubic mètre: 4000 hours per year.
Oil Gas	,,	0·050	20·00	At 0·30 franc the cubic mètre: 500 hours per year.
Oil Gas	,,	0·046	17·80	At 0·30 franc per cubic mètre: 4000 hours per year.
Gramme Machine (new type)	,,	0·0042	1·78	With steam motor: 500 hours per year.
Gramme Machine (new type)	,,	0·0016	0·56	With steam motor: 4000 hours per year.
Gramme Machine (new type)	,,	0·004	1·60	With hydraulic power: 500 hours per year.
Gramme Machine (new type)	,,	·0011	0·44	With hydraulic power: 4000 hours per year.

With old forms of machines, the advantage was much less; there is however always a considerable difference in favour of the electric light.

Let us take for example the case where a machine of 100 burners is employed, where the cost of a motor is taken into account and where interest is calculated at 15 per cent. instead of at 10 per cent., as previously reckoned.

We cannot do better than reproduce the figures given by M. Heilmann on the cost of machines working for three years in the Ducommun workshops, at Mulhouse, noting that the interest is very high, since the Gramme machines are not susceptible to deterioration. This arrangement is then as favourable as possible, from an electrical point of view.

Four machines with four regulators cost per hour:

EXPENDITURE FOR LIGHTING PROPERLY SO CALLED.

	Francs.
Carbon for regulator: for 4 regulators	0·88
Consumption of steam for 4 machines	0·36
Superintendence	0·30
For 4 luminous foci	1·54

INTEREST AND DETERIORATION.

The introduction is estimated:

	Francs.
For the Gramme machines and the regulators	9,000
For the motor power	8,000
Total	17,000

	Francs.
15 per cent. interest, wear and tear, and maintenance, 2550 francs divided over 500 hours' lighting per annum	5·10
Total expenditure per hour for 4 luminous foci ..	6·64

If in the special case before us, we wish to make comparison between the cost of lighting the foundry of the Ducommun shops, by the electric light or by gas, the following table will supply the data:

Lighting by Means of Gas obtained from Oil.			Lighting by Means of the Electric Light.		
Power of light expressed in Gas-burners.	Cost per Hour.		Equivalent of the power of the Electric Light from 4 Regulators expressed in Number of Gas-burners.	Cost per Hour.	
	Without Interest or Deterioration.	With Interest and Deterioration.		Without Interest and Deterioration.	With Interest and Deterioration.
burners. 442	francs. 11·05	francs. 15·03	burners. 442	francs. 1·54	francs. 6·64

From the above table we may draw the following conclusions: With equal *light emission*, the electric light costs less than gas, and this in the ratio of about 1 to 2·26 with interest and deterioration, and of 1 to 7·17 without interest and deterioration.

The following are figures that serve as basis in the preceding calculation:

Number of hours of lighting per annum: 500.

Power of light from 4 regulators: 320 Carcel burners (each of 0·0235 mètre exterior diameter, consuming 40 grammes of oil per hour).

Power of a Carcel burner: 8·69 stearine candles of ten to the kilogramme.

Test of a gas-burner consuming in one hour 100 litres of gas: 6·280 candles.

Cost of 1 cubic mètre of gas: 0·25 franc.

Cost of introduction of gas per burner: 30 francs.

To complete the data relative to the comparative expenditure for gas and electric lighting in the manufactures, we will give an estimate made for a spinning mill of 800 looms.

The introduction of gas was taken on the following basis:

Number of burners	415	
Number of hours of night work per year	500	
Cost of introducing gas	12000·00	francs.
Price of a cubic mètre of gas	0·25	francs.
Cost of gas per year	5486·85	„
Interest, 12,000 francs at 10 per cent. ..	1200·00	„
Maintenance of apparatus and contingencies	263·00	„
Total cost of gas-lighting per year ..	6950·10	„

Corresponding electric lighting includes:

6 machines at 1500 francs	9000	francs.
6 regulators of 300 burners at 450 francs ..	2700	„
Wires and mounting	1300	„
12 horse-power steam motor	8000	„
Total cost of electric apparatus	21,000	„

Power necessary to work the machines 12 horse-power:

Consumption of electric carbons 240 mètres at 2·5 francs	600 francs.
Consumption of coal, 10 tonnes at 30 francs	300 „
Interest on 21,000 francs at 10 per cent. ..	2100 „
Annual maintenance and contingencies ..	1600 „
Total cost of electric lighting per year ..	4600 „

The electric lighting in this case costs annually 33 per cent. less than that by gas, gives six times more light, and suppresses all danger of fire.

CHAPTER XI.

LIGHTING BY INCANDESCENCE.

Use of Geissler Tubes—Report presented to the Academy of Sciences by M. Coste, in the name of M. Gervais—King's Invention—Lodyguine's Lamp —Wild's Report to the St. Petersburg Academy—Konn's Lamp—Bouliguine's Lamp—Experiments by the Author on Lighting by Incandescence —Chérémeteff and Fontaine's Lamp.

As we have said, the voltaic arc is eminently convenient for the lighting of large uncovered spaces, or large halls without interior partitions, but when it is required to light small places or very subdivided localities, it is much more advantageous to employ gas, petroleum, or even ordinary oil.

There are numerous works on the construction of small electric foci, but to the present day none of the means devised have given practical results. It has been endeavoured to use Geissler tubes, and small incandescent carbons, and if these two means have not been successful, they offer nevertheless sufficient interest that we should devote some pages to their description.

It is well known that Geissler, an artist at Bonn, constructed the first tubes blown in various forms, closed hermetically and containing only traces of various vapours. These tubes put into communication with a current, by means of platinum wires fused into the glass, from a Ruhmkorff coil, produce a stratified light, that is to say, composed of fine transverse layers separated by dark layers continually agitated. At the same time the sides of the tubes present a brilliant appearance, to which the term fluorescence has been applied.

On March 27, 1865, M. Coste presented to the Academy of Sciences, in the name of M. Gervais, the following report:

"The apparatus was constructed by M. Ruhmkorff, who has acquitted himself of his task with his usual care and ability. It is a case or box in bronze, mounted on four feet, and its cover

or lid is hermetically closed by means of a press-screw, and between the two surfaces thus brought into contact is a caoutchouc washer. To the cover is attached a ring, serving as a suspension to the optical apparatus. The case contains two bichromate of potash elements closed in their turn by plates to which strips of copper are solidly screwed. The poles of the current furnished by these two elements may be put at will into communication with the bobbin, and the induced current is transmitted to a Geissler tube by two wires covered with india-rubber. This tube, of proper form and filled with carbonic acid, is enclosed in a glass cylinder with thick sides, furnished with copper armatures, and into which water cannot penetrate. This is the lighting part of the apparatus. With this instrument a soft light is obtained, similar to that now employed by miners. It resembles in certain respects that given by phosphorescent animals, but is more intense. It can be seen even when the apparatus is several mètres under water. It would doubtless serve to attract fish, as does the phosphorescence of certain species, and it would also serve to light limited spaces, situated beneath the surface of the water, or for floating signals. The captain of the 'Devoulx,' commanding the southern coasts of France, employed this apparatus in the port of Cette, in September last. It remained immersed for nine hours, and it gave light for six hours under these conditions, as well as when charged at Montpellier. The phosphorescence may be of longer duration. A second trial, made at Port Vendres, on board the 'Favori' (Captain Trotabas), was equally successful."

The light obtained by the Geissler tube is so feeble, that it can never be utilised practically, and numerous trials made in mines and powder mills have been without result.

Lighting by incandescence has been studied for a long time; but its application generally presents so great difficulties, that at the present day it may be considered as within a purely scientific domain, although a certain number of apparatus exist working moderately well.

The first document on the question that we have found, is an English patent of the 4th November, 1845.

Mr. King, the inventor, enters into some exact details of his

idea, and presents some considerations which tend to prove that magneto-electric machines, powerful enough to produce light, already existed in 1845.

The following are the principal passages from this patent:

The invention has for its basis the use of metallic conductors, or of continuous carbons, heated to whiteness by the passage of an electric current. The best metal for this purpose is platinum, the best carbon is retort carbon.

When carbon is employed, it is useful on account of its affinity for oxygen at high temperatures to cover it from air and moisture, as indicated in Fig. 45. The conductor C rests on a bath of mercury; the bar B is in porcelain, it serves to support the conductor C; the conductor D is fixed on the bell by a hermetically sealed joint. The carbon rod A rests at top and bottom on conducting blocks and becomes incandescent by the passage of an electric current.

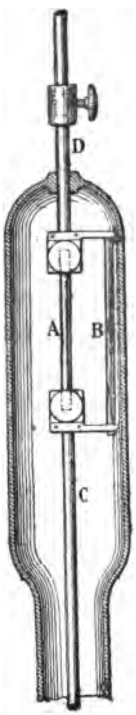

FIG. 45.
KING'S LAMP.

A vacuum is previously established in the bell, and the apparatus veritably forms a barometer with one of the poles of the battery in communication with the column of mercury, and the other with the conductor D.

In order to obtain an intermittent light, the circuit can be periodically interrupted by a clockwork movement.

The apparatus properly closed may be applied to submarine lighting, as well as to the illumination of powder mills and of mines, especially where the danger of explosion is feared, or the rapid inflammation of very combustible substances.

When the current is of sufficient intensity, two or a larger number of lights may be placed in the same circuit, care being taken to regulate the power of the magneto-electric machines, or the elements of the battery producing the current.

In 1846, Greener and Staite filed a patent for a lamp, analogous to King's, pointing out that they freed the carbon,

before use, from impurities by treatment with nitro-muriatic acid.

In 1849, Petrie concludes the description of a patent for a lamp with the following remark:—"A light may be produced by passing an electric current through a short and thin conductor, which heats and becomes luminous; but the majority of substances fuse and burn rapidly: however, I obtain a good light by using iridium, or one of its alloys. Iridium may be fused so as to produce an ingot whilst it is submitted to the heat of the voltaic arc; afterwards it may be decarbonised and rendered more malleable. It can be cut into small pieces of 0·001 mètre diameter and 0·010 to 0·020 mètre length, that can be fixed upon two insulated metallic supports, which are in connection with the two wires of a proper galvanic battery. There is then obtained a beautiful light."

Several other patents have been taken out in America, France, and England for the same kind of idea; but none of these appear more complete, more explicit, and more practicable than King's; it is then useless to continue our nomenclature.

Lighting by incandescence, and the principle of its production, had for a long time fallen into oblivion, when in 1873 a Russian physicist, M. Lodyguine, resuscitated both, and invented a new lamp, which has since been perfected by Messrs. Konn and Bouliguine.

In 1874, the St. Petersburg Academy of Sciences awarded a high prize to M. Lodyguine. The following includes some extracts from the report presented on the occasion by M. Wild, director of the Imperial Observatory; this report, as we shall see, includes several capital errors:

"It has long been known that we can employ the heating faculty of the electric current, even without the aid of gas, as in the luminous galvanic arc, to heat a solid body to whiteness. On this principle there are often thus heated thin platinum wires, which are bad conductors, by causing them to be traversed by a powerful electric current. The light obtained by this process is much more feeble and more constant than the electric light from carbon; it can also be extended further, and may be increased or diminished at will; nevertheless it has never found

practical use, because it is too feeble compared with its cost, and because when it is desired to give greater intensity, there results fusion of the platinum wire, which in general is not homogeneous throughout.

"M. Lodyguine was the first who had the idea of replacing the platinum wire, in these combustion experiments, by small bars of carbon (coke) analogous to graphite, that is to say, a good conductor, and thus resolved the problem of electric lighting.

"The advantages of this substitution of the carbon for platinum are so obvious from a theoretical point of view, that it is astonishing, as is always the case with important inventions, that no one had the idea sooner. Carbon possesses at equal temperature much greater power of radiation than platinum; the capacity for heat of platinum is superior (nearly double) that of the carbon in question, so that the same quantity of caloric raises the temperature of a small bar of carbon to a degree nearly twice that attained by a platinum wire of the same volume. Besides the resistance of the carbon in question, as a conductor of electricity, is nearly 250 times greater than that of platinum; it results that the small rod of carbon may be fifteen times thicker than a platinum bar of the same length, and that the current traversing it will engender the same quantity of heat. Finally the carbon may by heated to the most extreme white heat without fear of fusion, as is the case with platinum. It is to these important theoretical advantages that is evidently due the great success of the mode of electric lighting proposed by M. Lodyguine.

"The sole inconvenience of the use of carbon instead of platinum consists in the fact that, in the combustion the carbon combines with the oxygen of the air, and is thus gradually consumed. M. Lodyguine has avoided this inconvenience by enclosing the carbon heated to whiteness by the electric current in a glass receiver hermetically sealed, and from the interior of which the oxygen is expelled by a most simple process.

"It is not within the province of the Academy of Sciences to give its judgment on the technical and other difficulties which will present themselves in the extended application of M. Lodyguine's invention, nor on the other hand, upon the

numerous practical advantages of this mode of lighting above all others; it will suffice to the Academy to state that, thanks to this invention, there is resolved in the simplest possible manner the great problem of subdivision of the electric light, and of rendering it constant,* in order to recognise M. Lodyguine as worthy, in consideration of the numerous applications of his invention, to obtain the Lomonossow prize."

In his lamp, M. Lodyguine employs carbon in a single piece by diminishing the section at the point of the luminous focus, and he places two carbons in the same apparatus with a small exterior commutator, in order to pass the current into the second carbon, when the first has been consumed. Nothing is less practical nor less studied than the apparatus of this inventor.

M. Kosloff, of St. Petersburg, who went to France in the hope of working the Lodyguine patent, perfected his lamp slightly, without, however, bordering upon anything passable.

In 1875, M. Konn, also from St. Petersburg, patented a more practicable lamp, represented in Fig. 46, which was constructed for the first time in Paris by M. Duboscq.

This lamp consists of a base A in copper, on which are fixed two terminals N for fastening the conductors, two bars C, D in copper, and a small valve K opening only from within outwards. A globe B, widened at its upper part, is retained on the base by means of a bronze collar L pressing on an india-rubber ring, exactly as occurs with the level-gauges of steam-boilers.

One of the vertical rods D is insulated electrically from the base, and communicates with a terminal also insulated. The other rod C is constructed in two parts: (1) of a tube fixed directly upon the base without insulation, and (2) of a copper rod split for a part of its length. This split gives elasticity, and admits of the rod sliding in the tube with only a small effort.

The retort carbons E, to the number of five, are placed between two small plates which crown the rods.

Each carbon is introduced into two small blocks, also of carbon, which receive the copper rods at their extremities. The rods also are equal in length at their lower ends, and of unequal length at their upper ends. A hammer I is hinged on the bar C,

* We shall see subsequently how the problem has been resolved by M. Lodyguine.

and rests only on a single rod of carbon at once. If this lamp is placed in circuit by attaching the two conductors from a battery to the terminals N, N' (the terminal or binding screw N' is hidden by the terminal N; but it is identical, and is not insulated from the base), the bar of carbon E is traversed by the current which passes by the aid of the hammer I, from the copper bar F, the two carbon blocks O, O, the copper bar G, and the plate crowning the bar D.

The vacuum has previously been made by putting the cock K in connection with an air-pump or other known pneumatic machine.

The rod E reddens, whitens, and becomes luminous. Its light is colourless, steady, and constant; but gradually the section diminishes, the rod breaks, and the light disappears. The hammer I then falls on another rod, and nearly instantaneously lighting is re-established.

When all the carbons are consumed the hammer rests upon the copper rod H, and the current is not interrupted. In this manner when several lamps are fed by the same electric generator, extinction of one does not cause that of the others.

To avoid the projection of small pieces of carbon and their blocks against the glass, M. Konn has placed at the lower part of his lamp a small copper tube M, which receives the *débris* until the plates are refurnished.

Three of these lamps were introduced two years ago at the house of M. Florent, a merchant of St. Petersburg, and put in action with an "Alliance" machine. Each carbon lasts about two hours, with the exception of the first, which is consumed nearly immediately; the light is very agreeable, but its cost considerably exceeds that of gas. M. Florent, whom we have had occasion several times to see, has informed us that the great advantage he has found in the employment of electric lighting was its cleanliness. His store-rooms contain much white linen that gas rapidly impairs, and on which electricity exercises no injurious influence. The bleaching economised fully compensates the supplementary cost necessitated by an important introduction, with but little regard to the light obtained.

M. Florent has not made any photometric measurement; but,

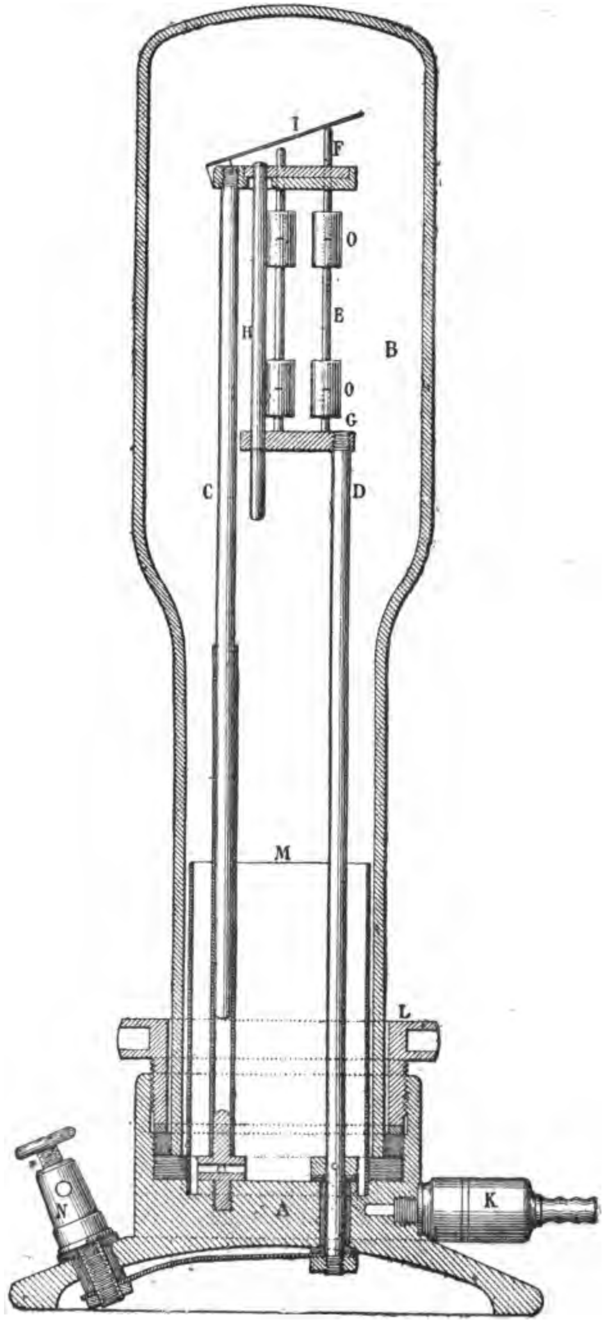

FIG. 46. KONN'S LAMP.

by comparison with gas, each Konn lamp has been valued at about 20 Carcel burners.

The principal cause of the great expense that the use of the light from incandescence entails, rests in the difficulty of preparing small carbons, which cost, as fitted, more than 5 francs per mètre.

A Russian officer, M. Bouliguine, has constructed a lamp (Fig. 47), which attains nearly the same end as that by M. Konn with a single carbon. It consists, like the preceding, of a copper base or socket, two vertical bars, two bars carrying the current, and an exhaust valve.

One of the bars is pierced with a small hole from top to bottom, and has nearly throughout its length a slot admitting the passage of two small lateral lugs.

The carbon is introduced into this bar like the lead of an ordinary pencil-case, and it is assisted to rise by a counterweight connected by two microscopic cables to lugs in the transverse support on which the carbon rests.

The part of the carbon which is to become incandescent is held between the lips of two conical blocks of retort carbon.

A screw placed on the base admits of increasing or diminishing the length of the bar which carries the upper conical block, and consequently of giving to the luminous part greater or less length.

The closing of the globe is effected by the lateral pressure of several india-rubber washers.

When the lamp is placed in circuit, the carbon rod reddens and illuminates until it is about to break. At this moment a small mechanism * commanded by an electro-magnet opens the lips of the carbon-holders, the counterweight above drives out the fragments that would remain in the notch, and the counterweight below raises the carbon rod which penetrates the upper block, and re-establishes the current. The mechanism again acts, but in contrary direction to its first manœuvre, the carbon-holders contract, and the light is renewed.

* The mechanism in question, which the scale of the engraving will not admit of showing, consists substantially of an iron armature placed in the interior of the lamp, and of two metallic rods acting on two cross levers jointed on to the ring surrounding the carbon-holders.

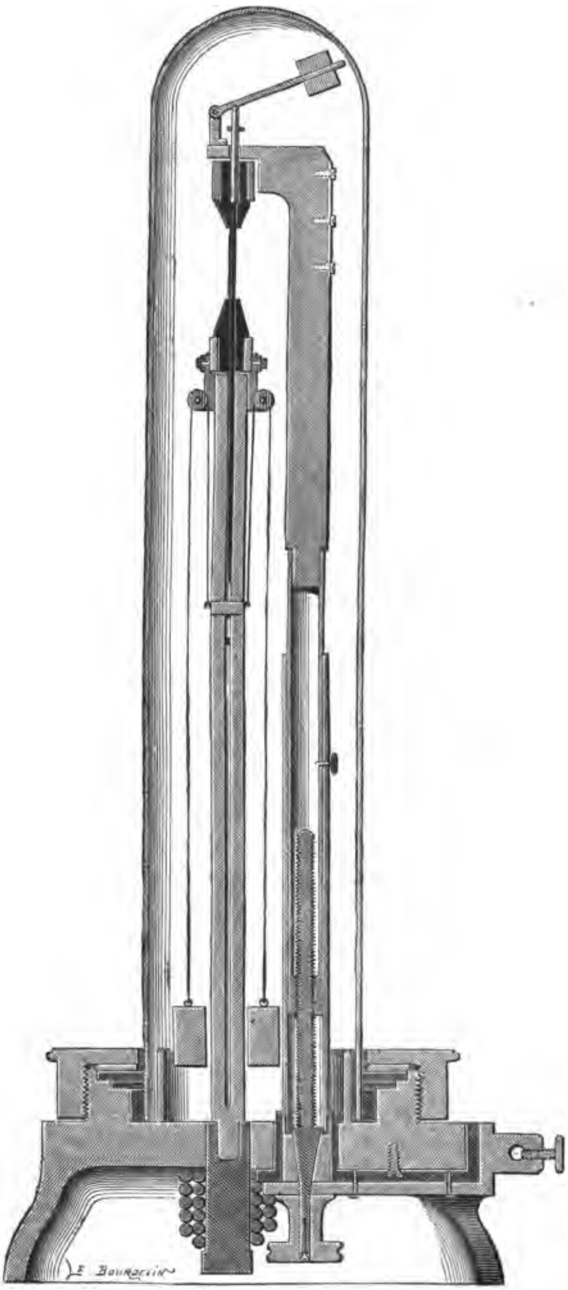

FIG. 47. BOULIGUINE'S LAMP.

We have several times tried this lamp, but we have never obtained good results. It includes too many moving parts, and the least obstacle prevents the play of the mechanism. However, we have observed that when by chance it works regularly, the contacts being better and less numerous than those of Konn's lamp, it needs less intense currents for the production of a given light. With a Gramme machine of 100 burners we have obtained with a single lamp as much as 80 burners, whilst with a Konn lamp we could never exceed 60 burners.

In order to realise the actual value of the system of lighting by incandescence, we have made a series of experiments with several Konn's lamps and a Bunsen battery of 48 elements, of 0·20 mètre height.

The first operation consisted in measuring the resistances of retort carbon of square section. The samples tested were 0·002 mètre in the side. The following results are from eight experiments:

Number of Experiment.	Length of Samples.	Resistance in Mètres of Telegraph Wire.
	mètre.	
1	0·100	16
2	0·100	14
3	0·100	15
4	0·100	14·50
5	0·100	19
6	0·050	7
7	0·050	9
8	0·050	7
Total	.. 0·650	101·50

Whence it results that the mean linear resistance of the retort carbon of 0·002 mètre is about 172, that of a telegraph wire of 0·004 mètre being taken for unity.

We subsequently rounded the carbons, so as to reduce their diameter to 0·0016 mètre, and regulated the length in such a manner as to obtain 0·018 mètre incandescent part. The vacuum was carried to about 0·70 mètre mercurial pressure.

The following results represent the mean of more than twenty series of experiments:

State of the Circuit.	Methods of Coupling the Battery.							
	2 Series parallel of 24 Elements.		3 Series parallel of 16 Elements.		4 Series parallel of 12 Elements.		1 Single Series of 48 Elements in Tension.	
	Galvanometer deflection.	Luminous Intensity of each Lamp.	Galvanometer deflection.	Luminous Intensity of each Lamp.	Galvanometer deflection.	Luminous Intensity of each lamp.	Galvanometer deflection.	Luminous Intensity of each lamp.
Circuit closed on itself	47	..	70	..	70	..	50	..
5 lamps	28	Reddish-white	17	Cherry-red	10 or 11	Dull-red	35	¼ burner
4 lamps	29	¼ burner	22	Reddish-white	16	Orange-red	38	2½ burners
3 lamps	38	1 to 2 burners	28	½ burner	26	¼ burner	41	3½ burners
2 lamps	40	3 burners	41 to 42	2½ to 3 burners	40 to 45	3 to 5 burners	44	5 burners
1 lamp	43	4 to 5 burners	49	11 to 12 burners	60	40 burners	45 to 46	6½ to 7 burners

The lamps were grouped like the elements of a battery in tension, then forming a single series.

In the following table are given the results obtained with lamps arranged in *batteries*, that is to say, on distinct circuits derived from the battery. Because of the considerable differences observed in the intensities of the light of each lamp during the same experiment, we give the total light instead of that produced by each lamp :

State of the Circuit.	Methods of Coupling the Battery.							
	2 Series parallel of 24 Elements.		3 Series parallel of 16 Elements.		4 Series parallel of 12 Elements.		8 Series parallel of 6 Elements.	
	Galvanometer deflection.	Total light emitted by the whole of the lamps.	Galvanometer deflection.	Total light emitted by the whole of the lamps.	Galvanometer deflection.	Total light emitted by the whole of the lamps.	Galvanometer deflection.	Total light emitted by the whole of the lamps.
Circuit closed on itself	58½	..	68	..	69	..	70	..
5 lamps.. ..	57	..	64½	½ burner	63½	2½ burners	60	..
4 lamps ..	56½	..	63	¾ burner	63	3 burners	59	..
3 lamps ..	56	1 burner	61½	2 burners	62	4 burners	58	¾ burner
2 lamps ..	55	5 burners	60	6½ burners	59	15½ burners	55	1½ burner
1 lamp	52½	9 burners	57½	54 burners	55	65 burners	46	8 burners

Several important observations were made during these experiments.

When the receivers are sealed and the contacts carefully put in line, the carbons last for a satisfactory period. The first carbon of a lamp never lasts for less time than a quarter of an

hour; sometimes it breaks at the end of thirty to thirty-five minutes, but that is very rarely; its average duration is twenty-one minutes. The succeeding carbons last upon an average for two hours, so long as the luminous intensity does not reach 40 burners, in which case the average duration is only half an hour. In the experiment of four parallel series of 12 elements, the five lamps being collected in batteries and one only lighted, the carbon, which gave 65 burners, lasted only twenty-three minutes as an average.

Attentive examination of incandescent carbons, through a strongly coloured glass, has shown that they are not uniformly brilliant. They present obscure spots, indicative of non-homogeneity, and the position of cracks which rapidly disintegrate the carbon.

The vacuum never being perfect in the receivers, the first carbon is in greater part consumed. It would appear that consequently upon the little oxygen contained in the lamp being transformed into carbonic acid and carbonic oxide, the carbon should be preserved indefinitely. But there is then produced a kind of evaporation which continues to slowly destroy the incandescent rods. This evaporation is besides clearly proved by a pulverent deposit of sublimed carbon, that we have found on the interior surface of the bells, on the several interior parts: rods, contacts, hammers, &c.

No bell has been cracked by heating or cooling during the whole of the experiments, extending over several months, but several of the necks have been broken by the too energetic closing of the joint.

The delicate part of the lamp is in the series of contacts which precede the incandescent rod. The carbons are got into straight line, which is indispensable to their duration, only with minute and long precautions. After rupture, the contact does not always occur automatically, and two or three times we have been obliged to shake the lamp to cause the lighting of the next carbon.

The maximum efficiency has occurred with a single lamp and with four elements in quantity; by employing two lamps and descending to two elements in quantity, the results were considerably diminished.

We have recently made similar trials with Gaudoin artificial carbons of the same section, and the results have been more satisfactory. Thus the total light produced with 48 elements in four series and a single lamp, reached 80 burners, and that produced with the same battery and three lamps, attained 30 burners.

The same battery coupled in tension and actuating a Serrin lamp gives a voltaic arc of 105 burners; but the light obtained by incandescence is much steadier and more agreeable to the eye.

From what precedes, it appears to result that King and Lodyguine's system is much more favourable to large foci than to the divisibility of the electric light; however it is proper to remark that when 10 burners per lamp are not exceeded, the carbons have a very long duration, whilst they are consumed very quickly for an intensity of 60 to 80 burners.

Only carbons of 0·0016 mètre diameter and 0·018 mètre luminous length were until then those tried; these behave very well with a strong current, but give no light with 12 elements. It became interesting to learn what light could be obtained with 12 elements by diminishing the length of the carbons. This was the object of a new series of experiments.

Five different combinations were attempted, by varying in turn the coupling of the battery, the diameter of the carbon and its length.

The best results were obtained with a single lamp furnished with Gaudoin carbons of 0·0016 mètre diameter, and of 0·015 mètre length, in the incandescent portion.

The light varied between 2 and 8 burners, but it was more often 5 burners. Each carbon lasted on average fifteen minutes.

We were about to repeat all these experiments, substituting for the battery a Gramme machine constructed to give the best useful effect; but the imperfections of the lamps, the difficulty of obtaining good contacts, the too minute care to be taken at the commencement of each operation, led us to decide to previously design a lamp more commodious and slightly more practical than that of M. Konn.

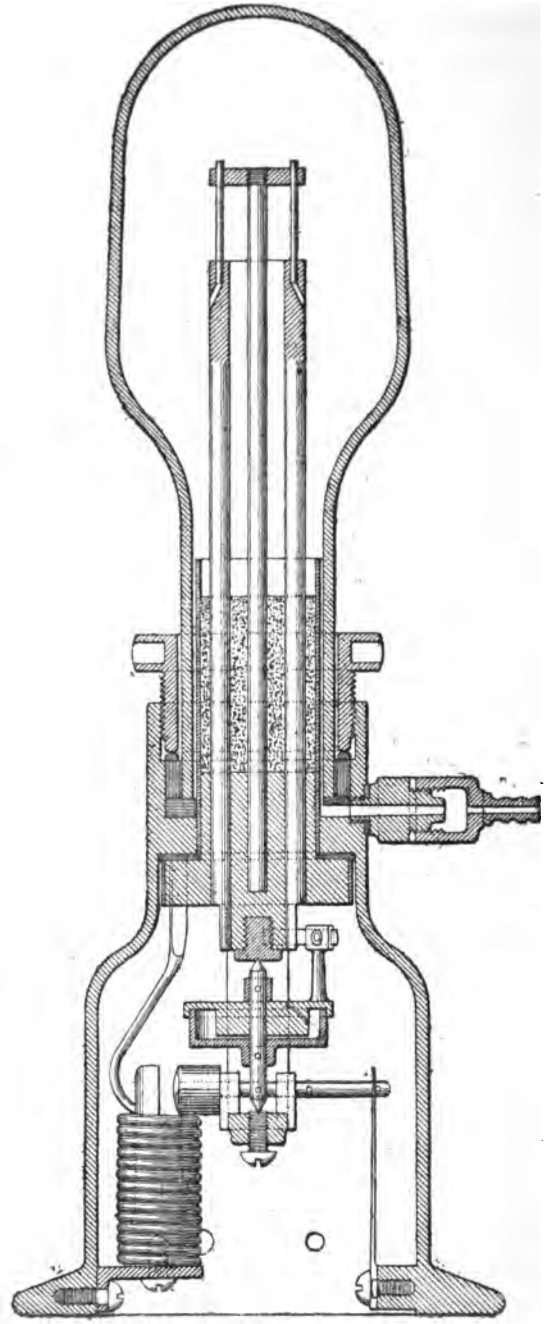

FIG. 48. FONTAINE'S LAMP.

This lamp, which we represent in Fig. 48, is at present under construction by M. Bréguet. It is characterised by the two following points: (1) the carbons are set in a groove at each of their extremities in rigid contacts and kept fixed, which admits of the lamp being placed in all positions; (2) the electric current passes automatically from one carbon to the other by the action of an electro-magnet interposed in the circuit.

A description, even summary, would not be of great interest, since the lamp is not yet finished; the engraving sufficiently indicates the arrangement we have adopted.

CHAPTER XII.

DIVISIBILITY OF THE ELECTRIC LIGHT.

General Remarks on the Divisibility of the Electric Light—Impossibility of establishing very small Luminous Centres with the means actually known—De Changy's Invention—Report of M. Jobart—Lacassagne and Thiers' Dividing Regulator—M. le Roux' Experiments—M. de Mersanne's Apparatus—M. Jablochkoff's Experiments at the Magasins du Louvre—A Recent Communication made by M. Denayrouse to the Academy of Sciences.

THE remarkable effects of the voltaic arc were no sooner foreseen than the idea arose of dividing the electric light, and even before the existence of a good regulator for a single light, King took out a patent for a lamp on the divisible system. The steps, however, that were being taken to perfect the single luminous centre had advanced so rapidly, that with an expenditure of 10 horse-power an artificial sun of an intensity of 4000 burners was produced. This grand result was due to the carbons of Foucault, Carré, and Gaudoin; to Serrin's lamps, Gramme's machines, and Sautter and Mangin's projectors. On the other hand, the plan of dividing the light made no advance, but remained still an object of experimental and speculative inquiry.

The merits of the systems of King in 1845, and of Jablochkoff in 1877, are of an exceptional character, and it would be a matter of difficulty to decide which of them approaches nearest to the true solution of the difficult problem of dividing the electric light. It must not, however, be thought that in face of these obstacles the idea of replacing gas by electricity will have to be entirely renounced, for science is far from having attained the last of its conquests by means of this mysterious fluid, which has already annihilated distance, and may also be said to have suppressed night; but despite the remarkable labours of M. Jablochkoff, and the no less remark-

able initiative of M. Denayrouse, there exists at the present time no sufficiently practical system of so dividing the light as to render it generally available for the purposes for which gas is used. Each decade gives birth to a new idea, the importance of which is exaggerated by rumour until, after a few unsuccessful trials, public interest abates, and nothing more is heard of the matter. In 1847, King's discovery of incandescent carbons was announced in England; in 1857, M. de Changy, in Belgium, substituted platinum for the carbon, and employed a regulator; in 1867, M. Le Roux published in France a method of passing a current alternately, and with great rapidity, through several ordinary regulators; and lastly, M. Jablochkoff, in 1877, caused sparks to pass through plates of kaolin, and by this means obtained a series of small lights.

There is no doubt that each of the systems proposed is capable of rendering important service in special cases, but the error that inventors have fallen into has been the claiming of too great a scope for their apparatus as leading immediately to the supplanting of gas. The electric light has already a vast field of application open to it, and Chapters VII. and VIII. treat of the great advantages attaching to its employment in a number of cases, but that it will some day entirely take the place of gas is extremely improbable. It has, in fact, only been since the introduction of electric lighting that our admiration for the facility with which gas can be divided and distributed has been fairly aroused.

By the term "divisibility of the electric light" we do not mean the production of several intense lights by means of one machine or battery, but simply the maintaining of a few small luminous centres, each equal to 1 to 15 Carcel burners. It has been proved beyond a doubt that several lamps can be kept in action by one magneto-electric machine, but the question is, whether the first cost and maintenance of such apparatus is not greater than that of a series of small machines each in circuit with a lamp. We have always favoured the latter method of lighting, although the other plan has received a large share of our attention, and there is a likelihood that M. Gramme will still have the honour of making it a practical success. At

present, however, the means proposed for attaining this divisibility of the light have been practically without success.*

We will now glance at the various systems devised for the solving of this problem. It has been shown that the invention of King, re-invented by M. Lodyguine, and improved by M. Konn, was better suited to a single light than to a divisible system. There are, however, some advantages connected with the burning of small carbons in a vacuum, inasmuch as the light is steady and the expense moderate. Before abandoning this method some new experiments should be made with shorter and thinner carbons of various qualities. Where a single lamp and great regularity of the light is needed, this system may come into use. The mode of operation adopted by M. de Changy has never been thoroughly known, but to judge from the following communication made by M. Jobart to the Academy of Sciences on the 27th of February, 1858, M. de Changy's laboratory experiments must have been perfect:

"I hasten to announce to the Academy the important discovery of the dividing of an electric current for lighting purposes. This current from a single source traverses as many wires as may be desired, and gives a series of lights ranging from a night lamp to a lighthouse lamp.

"The luminous arc between two carbons produces, as is well known, a very intense, flickering, and costly light. M. de Changy, who is a chemist, mechanician, and physicist, is thoroughly conversant with the latest discoveries, and has just solved the problem of dividing the electric light.

"In his laboratory, where he has worked alone for the past six years, I saw a battery of twelve Bunsen elements producing a constant luminous arc between two carbons in a regulator of his own invention, this regulator being the most simple and perfect I have ever seen. A dozen small miner's lamps were also in the circuit, and he could at pleasure light or extinguish either one or the other, or all together, without diminishing or

* This opinion must be taken to refer entirely to the present time, and in no way to prejudge the future; from time to time we have drawn attention to the experiments which have been made in this direction, with a view to the placing of a fair statement before everyone who wished for our opinion on the subject.

increasing the intensity of the light through the extinction of the neighbouring lamps. The lamps, which are enclosed in hermetically sealed glass tubes, are intended for the lighting of mines in which there is fire-damp, and for street lamps, which would by this system be all lighted or put out at the same time on the circuits being opened or closed. The light is as white and pure as Gillard's gas, with which it has one point in common, namely, its production by the incandescence of platinum. The gas-pipes are replaced by simple wires, and no explosions, bad smells, or fires can take place.

"The trials that have been hitherto made with the object of producing an electric light by means of heated platinum, have failed on account of the melting of the wires. This difficulty has been overcome by M. de Chanzy's dividing regulator. The cost of the light is estimated to be half that of gas. A lamp placed at the mast-head of a ship, would form a permanent signal for about six months, without the necessity of changing the platinum. With several such lights placed in tubes of coloured glass, it would be easy to telegraph by night, as they could be extinguished and relighted rapidly from the deck. For lighthouse purposes considerable amplitude can be given to the light. I also saw a lamp so arranged in a thick glass globe, that it could be immersed to considerable depths, without being overturned by any movement. This lamp had already been used in the taking of fish, which were attracted towards the light.

"The above slight description will suffice to show to what a variety of applications this discovery can be put. The communication which I have had the honour of laying before the Academy is founded upon no illusion, a lamp was to my astonishment lit in the hollow of my hand and remained alight, after I had put it in my pocket with my handkerchief over it."

It must be borne in mind that the above communication was made by (M. Jobart,* of Brussels) a thoroughly skilled man of

* M. Jobart was born at Bourgogne. He was at the time this communication was made Director of the Royal Museum of Belgium Industry, Chevalier of the Legion of Honour and of the Order of Francis the First of Naples, President of the Society of French Inventors, President of the National Academy of Agricultural and Manufacturing Industry, besides being a Member of the Scientific Institutions of the United States, France, &c.

science, and one not likely to be carried away by the enthusiasm of an inventor.

We have not seen any drawings of the regulator invented by M. de Changy, but we have seen that of MM. Lacassagne and Thiers, patented by them in 1854.

The theory of this apparatus is explained in the following description taken from the patent:

When in any part of the circuit the current has to pass through a liquid of less conductivity than that of the reophores, the intensity or quantity of electricity passing in a given time is inversely proportional to the resistance of the interposed liquid. This resistance may be increased or diminished, either by an increase or decrease of the conducting power of the liquid or of the surface immersed. The magnetic force of an electro-magnet varies with the intensity of the current. If the surfaces of the conductors immersed in the liquid are of an unchangeable metal, we obtain in a free state the gas arising from the decomposition of the liquid; the quantity of this gas in a given time being in direct proportion to the intensity of the current.

MM. Lacassagne and Thiers divided one of the conductors of a battery in action into two parts, attached a plate of platinum to each extremity, and suspended the plates in the interior of a glass gasometer containing acidulated water. The bell of the gasometer was raised or lowered by the inlet or outlet of the gas, produced by the current. The ascent of the bell produced of course a diminution of the galvanic intensity, whilst its descent produced the opposite effect. An electro-magnet, with an armature in the form of a lever and an opposing spring, completed the arrangement. The apparatus worked in the following manner:

The spring was first adjusted to the strength of the current determined upon. As long as the magnetic attraction was greater than the tension of the spring, the armature remained in contact, and as the gas which was developed had no outlet, the bell of the gasometer was raised, thereby diminishing the surface of the platinum in contact with the liquid, and consequently the intensity of the current. There would occur a

moment of equilibrium and also when the force of the spring exceeded that of the magnet; the armature receded, and in so doing opened a trap which allowed of the escape of a portion of the gas until the normal position of the bell was again obtained. When such a regulator was accurately adjusted, the tap remained constantly partly open, and the armature very close to the electro-magnet without touching it. This regulator, if applied to each of the small lamps of M. de Changy, would prevent the combustion of the platinum wires, but the complication which would arise from this arrangement would render it inapplicable, even if no other practical defects had been found to arise from its use.

MM. de la Rive and Elie Wartmann, both physicists of Geneva, observed that with a very sensitive regulator, and a battery in good working order, a current could be interrupted for the thirtieth of a second without any variation of the arc; but with an interruption of longer duration the arc became enfeebled, and vanished altogether after the current had ceased for the tenth of a second. M. Le Roux, profiting by this observation, has obtained some very beautiful results, which he has thus described in a communication to the Academy of Sciences, dated the 30th of December, 1867:

"The spark from an electric battery is in general incapable of passing between two separated conductors. (A battery of 3500 elements insulated with the greatest care is necessary for the production of a spark having the length of only a fraction of a millimètre.) The induction currents from magneto-electric machines have a much higher tension, and this accounts for the light produced by alternate-current machines. I have obtained the same effects with a battery of fifty Bunsen elements, and with the current interrupted during the twenty-fifth part of a second, a spark leaped over an interval of about three millimètres. This fact led me to a solution of the problem of divisibility. When a current passes between two conductors, so as to produce a voltaic arc, it has hitherto appeared probable that this passage was due to the elevation of the temperature, and not to the arc itself. The conductibility of the interposed

medium is perhaps only an extension of the fact noted by M. Edouard Becquerel in the case of heated gases, whose conductibility was considerably increased by the enormous elevation of the temperature."

"The carbon electrodes form perhaps a vapour of considerable tension at this high temperature, and this vapour tends to increase the conductibility of the arc." By means of a distributing wheel revolving with great rapidity, M. Le Roux sent the current of a Bunsen battery alternately into two regulators, in such way that it traversed each of them during the same number of fractions of a second, and he thus succeeded in dividing the light. The lights were under these conditions perfectly equal.

M. de Mersanne, in 1873, took out a patent for the dividing of electric currents on the same principle as that of Le Roux. The mechanical construction of the invention is of so elementary a nature, and so little worth patenting, that we should have made no mention of it, had not M. de Mersanne in the following year made an addition to the patent, which if not practical, is at least original. The distributing wheel of M. Le Roux he has replaced by a horizontal spindle, carrying a series of cams. By means of these cams, a reciprocating motion is given to some rollers jointed to vertical metallic arms which are plunged into and withdrawn from cups filled with mercury. When the spindle revolves at a high rate of speed, several lamps are put successively into contact with the electric current, whereby a single source of electricity is divided into equal or unequal portions, according to the combination given to the interruptors.

Last year, when travelling through the principal towns of the United States, we endeavoured to discover what progress had been made in America, in the matter of electric lighting, but we were unable to see anything of a practical nature. Many physicists had been experimenting with a view to the division of the light, but none of them were in a position to show us an apparatus worthy of even being mentioned. We will only refer here to a patent taken out by Mr. Henry Woodward, in 1876.

This invention relates to the incandescence of a carbon in a

rarefied gas, having the property of not combining chemically with carbon heated to redness.

We have already mentioned the arrangement of parallel carbons forming the candles of M. Jablochkoff, and will now give some account of the experiments actually made at the Grands Magasins of the Louvre, and also of the note presented by M. Denayrouse to the Academy of Sciences on the 17th of April, 1877. At the Magasins the object was to increase the light in the Marengo Hall, which was supplied with eleven lustres, and also received light from the halls surrounding it. Around the Marengo Hall, at about two-thirds of the height, there is a gallery on which the electric lights were placed. Two "Alliance" machines worked six candles, and by an ingenious arrangement the candles when burned out were replaced by others, without causing a sensible diminution of the light. The candles were arranged in diffusing globes, and the light was projected forward by means of reflectors. Two sticks of Carré's carbons, 4 mm. in diameter and 12 cm. long, insulated with a thin plate of silicious matter, and fixed in two copper tubes, which were united by a plug of asbestos, formed the candles. A slip of carbon laid across the top of the two carbon sticks served to light them. It was difficult to judge of the intensity of the electric light, as the gas was not entirely extinguished, and the neighbouring galleries added their light also, but with a pocket photometer each candle was found to give about 20 to 25 Carcel burners. The irregularities were not great, but of tolerable frequency. A slight and continual flickering was perceptible in all the lights, arising from the nature of the carbons and changes of speed of the motor. An effect of a special kind, which was no doubt due to the ebullition of the silicious substance interposed between the carbons, gave a singing sound to the diffusing globe. We were told that the candles would last three-quarters of an hour; at the Louvre they were renewed every half hour. The advantages of this mode of lighting can only be decided by knowing the cost of machines, motor, &c., the expense of erecting them, and the cost of maintenance per hour for each unit of light. A comparison could then be made with the cost of other existing

electric lights, such as those erected at M. Ménier's chocolate factory at Grenelle.

The labours of M. Jablochkoff have, from a purely scientific point of view, an undoubted value, as he has demonstrated that these voltaic arcs can be maintained in the circuit of a single current, and that two parallel carbons separated by a silicious plate produce a light less intense, it is true, than that of a regulator with ordinary retort carbons, but quite as regular and less intermittent. The possibility of dividing the electric light experimentally, or for purposes of scientific demonstration, was proved by M. Florent at St. Petersburg with Konn's lamp, but the novelty of the newer experiments is that the carbons are burned in the air, and not in a vacuum, as in M. Konn's arrangement.

There is no doubt that M. Jablochkoff, with the active co-operation of M. Denayrouse, will succeed in making the light more economical, and in considerably reducing the large outlay which his system necessitates; but as far as the application of the light to industrial purposes is concerned, the experiment at the Magazins of the Louvre proves nothing whatever. In fact, the only inference to be drawn therefrom is that the cost of this new method of electric lighting is much higher than that of the old system.

The two "Alliance" machines and the six standards for carrying the candles employed in the Jablochkoff arrangement cost at least as much as six Gramme machines and six Serrin lamps. The six candles give 240 Carcel burners,* whereas six Gramme machines with Gaudoin's carbons give 3000 Carcel burners. Taking, then, the first cost of plant as equal, the system with regulators gives twelve times more light than that with candles.

Taking the horse-power absorbed by the two "Alliance" machines at a minimum, namely, 5 horse-power, two Gramme machines with the same power would produce 1000 Carcel

* These figures must not be taken as absolute. Our estimate was 20 to 25 Carcel burners, and observations made independently by two other persons gave 22 and 30 Carcel burners. But as it is difficult to take exact measurements, we will reckon 40 burners to one Jablochkoff candle. Even if we double this number, the result of our comparison will not be altered to any appreciable extent.

burners, in place of the 240 burners given by the six Jablochkoff candles. In this respect the advantage is again considerably in favour of lighting by means of regulators. The superiority of the old system is established in the most convincing manner by comparing the consumption of carbons.

An electric candle costing at least half a franc lasts half an hour, being at the rate of 1 franc per hour for 40 burners and 12½ francs for 500 burners. With ordinary carbons, the same quantity of light is produced at M. Ménier's for a quarter of a franc; the cost of the candles is therefore fifty times greater than that of regulator carbons. We cannot repeat too often our opinion that M. Jablochkoff will soon succeed in reducing in a certain degree the heavy expenses to which we have just drawn attention.

For instance, the "Alliance" machines are dear, but it is possible to manufacture them at a lower cost, and the candles can also be made more economically. The only fact which we insist upon is, that it is materially impossible to replace advantageously the regulators by candles.

The experiment made at the Grand Magasins of the Louvre was very interesting; it attracted the public, and the journals spoke of it in terms of praise. If not absolutely practical, it yet deserves public attention as being the germ out of which in future a great success may grow. In a word, neither a favourable nor an unfavourable conclusion can be deduced from this experiment, which is perhaps a step towards the solution, but certainly does not satisfactorily solve the problem. The difference of colour between the electric light and gas-light was plainly shown, but this difference was also observed some years ago on the Boulevard des Italiens, when M. Tessié du Motay made some experiments with the oxy-hydrogen light.

M. Denagrouse's note to the Academy related to the complete suppressing of the carbon in the production of the electric light. M. Jablochkoff conceived the idea of introducing into the circuit of a magneto-electric machine the primary wire of a series of induction coils; in the secondary wire of each bobbin is placed a plate of kaolin, through which the induction sparks pass. The interposed plate of kaolin gets hot, reddens, and at last becomes

luminous. Around the edge of the plate is placed a priming of a better conducting substance than the kaolin itself. By this arrangement M. Jablochkoff hoped to produce fifty lights with a single magneto-electric machine. The aspirations of MM. King, Lodyguine, Konn, Kosloff, and de Changy were of a like nature, and we wish M. Jablochkoff better success than his predecessors obtained.

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